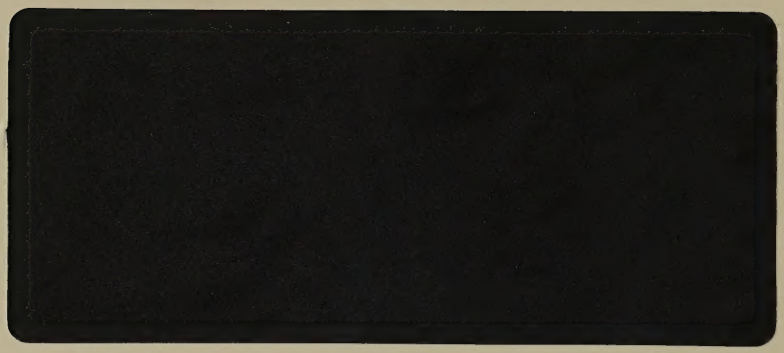
Strippable Coal Reserves of Montana



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STRIPPABLE COAL RESERVES OF MONTANA

Location, Tonnage, and Characteristics of Coal and Overburden

by

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ABSTRACT

An investigation was made to determine the location and extent of large blocks of strippable coal in Montana. By using published reserve data as a base and adding drill hole data contributed by companies owning or leasing coal lands, 37 deposits containing 12.7 billion tons of strippable coal were delineated. All strippable deposits are in the Fort Union region of eastern Montana.

Only beds 5 or more feet thick were included in estimates of strippable reserves; most of the beds are under less than 120 feet of overburden, and all are under less than 200 feet.

INTRODUCTION

This report is the first of a series on strippable coal deposits in Montana, Wyoming, and North Dakota. The purpose of the series is to define the location, extent, and other characteristics of the major strippable coal deposits in each of these States.

Several factors recently have stimulated interest in the development of coal resources in Montana, particularly the substantial strippable reserves in the eastern portion of the State. One important factor is the increasing need for electric power. Several additions to the thermal-electric generating capacity of Montana are planned or are under construction. If major power markets can be developed, perhaps through extra-high-voltage interties with more populous regions, such as the Pacific Northwest, then substantial additions ultimately will be made to thermal power generating capacity in or near the Montana coalfields. Another factor stimulating interest in large blocks of low-cost coal is the impending development of processes for the economic conversion of coal to liquid and gaseous hydrocarbon fuels. A 100,000-bpd conversion plant producing liquid products at a conversion efficiency of 60 percent would require a Btu input equivalent to 18 million tons of subbituminous C coal per year, and one of the same efficiency producing 250 million cu ft of gaseous products per day would require at least 7.5 million tons of the same rank coal per year. Strip mines serving such plants would be among the largest coal mines in the world, requiring strippable coal reserves of 200 million tons or more.

All published information on coal occurrences in Montana was analyzed. Firms and individuals engaged in exploration and acquisition of coal lands in Montana were consulted to obtain supplemental information. Coal outcrop and reserve data in reports of the U.S. Geological Survey were incorporated when available. By utilizing measurements of the stratigraphic interval between nearly flat-lying successive coalbeds, known bed thicknesses, and plan maps

showing the horizontal extent of coal outcrops, it was possible to delimit potential stripping areas. Cursory examinations were made of the coalfields in 1966 and 1967. Factors that would affect strip mining, particularly coal and overburden characteristics, were noted.

Where stripping limits had not been determined or topographic data were not available, it was necessary to delimit the area of a potential open pit on a strippable coalbed by using the mapped outcrop of a second coalbed lying stratigraphically above the strippable bed. In cases where the nearest mapped outcrop of an overlying coalbed is more than 120 vertical feet above the bed of interest, the location of the highwall (pit limit) was inferred by interpolating between the two outcrops.

Tonnage figures in this report include total known and indicated strippable coal reserves for all deposits on which records exist of coal and overburden thicknesses. Thirty-two maps have been prepared that show 37 deposits containing 12.7 billion tons of strippable coal. The deposits are located on figure 1 and listed in table 1.

All major strippable coal deposits in Montana occur in the Fort Union Formation of Paleocene age in the eastern part of the State. This area also contains more than 90 percent (215 billion tons) of Montana's 222-billion-ton reserve of mapped and measured coal within 3,000 feet of the surface.

ACKNOWLEDGMENTS

Recognition is due the several authors of U.S. Geological Survey publications concerned with the occurrence of coal in eastern Montana, particularly those individuals whose contributions are cited in the bibliography at the end of this report. Detailed data from drilling programs were provided by Garth Duell of Pacific Power & Light Co., George Nugent and Cliff Artis of the Big Horn Coal Co., S. L. Groff of the Montana Bureau of Mines and Geology, Tom Wollenzien and Ralph Watson both formerly with the Great Northern Railway Co., Robert Rovelstad of Baukol Noonan, Inc., and Virgil W. Carmichael formerly with the Northern Pacific Railway Co. Grateful acknowledgment is extended to each.

PREVIOUS INVESTIGATIONS

During 1950-51, at the request of the Bureau of Mines, the U.S. Army Corps of Engineers retained the engineering consulting firm of Ford, Bacon & Davis as prime contractor for a survey of the synthetic liquid fuels production potential of coal in Montana. The subsequent

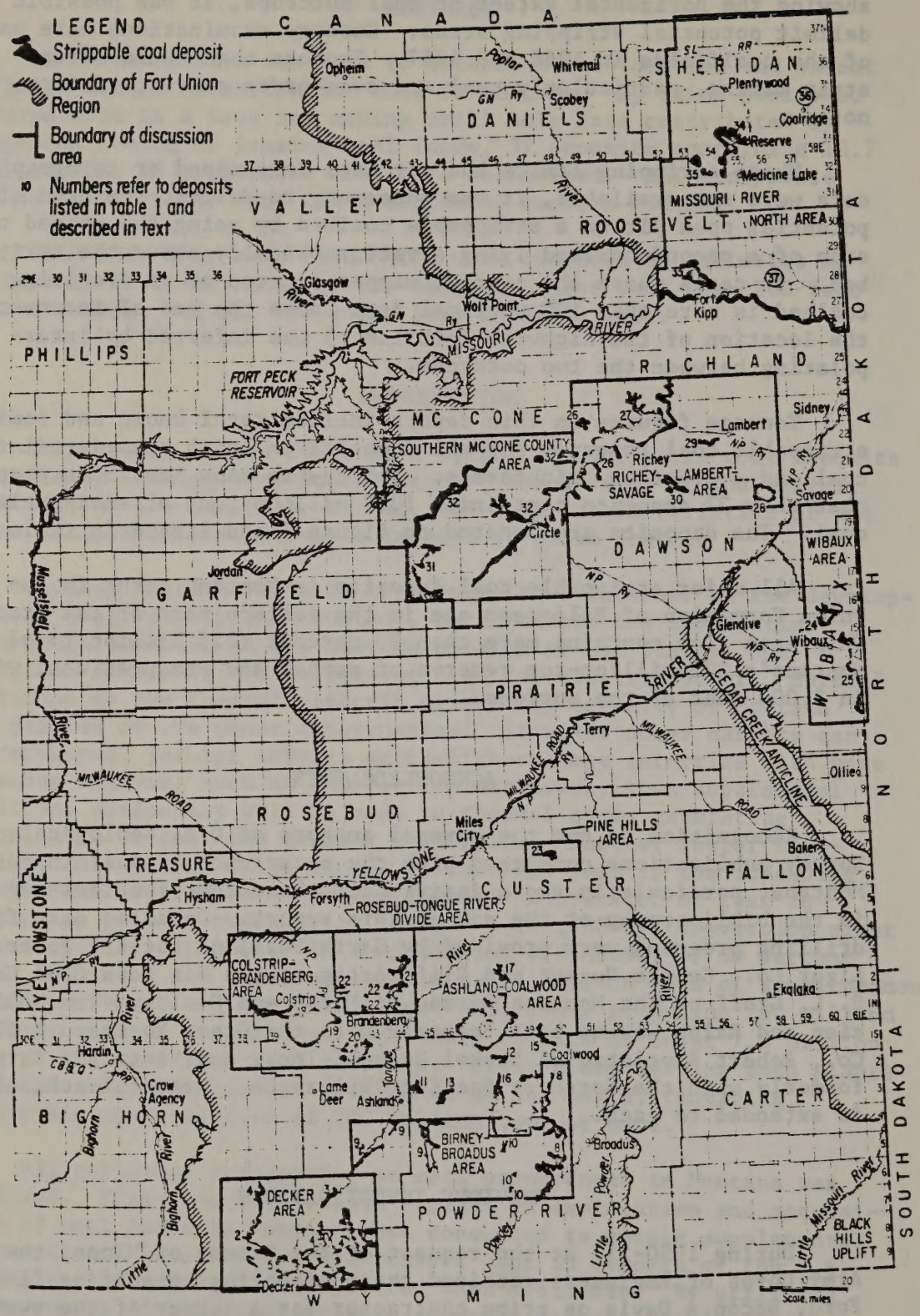

FIGURE 1. – Location of Strippable Coal Deposits in Montana.

TABLE 1. - Strippable coal deposits in Montana

Area and deposit	Location number[1/]	Strippable reserves, millions of tons	Maximum overburden, ft
Decker:			
Roland	1	313.5	120
Smith	2	228.1	120
Brewster-Arnold	3	71.2	120
Anderson	4	300.8	120
Dietz west of Tongue River	5	790.0	200
Dietz east of Tongue River	6	230.8	120
Dietz No. 1	7	331.0	120
Birney-Broadus:			
Broadus	8	473.6	150
Knoblock	9	494.9	200
Pawnee	10	27.7	50
Ashland-Coalwood:			
Cook Creek	11	34.3	120
Cottonwood Creek	12	40.7	120
Home Creek	13	41.1	120
Foster Creek	14	1,310.8	120[2/]
Sand Creek	15	68.9	120
Pumpkin Creek	16	1,901.0	200
Tongue River-Pumpkin Creek divide.	17	60.8	200
Colstrip-Brandenburg:			
Castle Rock-Armells Creek	18	428.3	120
South Coal Bank Coulee	19	91.6	130
Greenleaf Creek-Miller Creek	20	191.2	110[2/]
Rosebud:			
Rosebud Creek-Tongue River divide.	21	209.9	150
Burley	22	33.1	50
Pine Hills:			
E	23	90.9	120
Wibaux:			
Four Buttes	24	93.3	120
Wibaux	25	753.6	120

TABLE 1. - Strippable coal deposits in Montana--Continued

Area and deposit	Location number[1/]	Strippable reserves, millions of tons	Maximum overburden, ft
Richey-Lambert-Savage:			
Carroll	26	345.4	100
Lane	27	561.5	120
Breezy Flat	28	200.0	120
Fox Lake	29	46.3	120
North Fork Thirteen Mile Creek	30	225.1	120
Southern McCone County:			
R	31	196.1	145
S	32	1,165.0	140
Missouri River North:			
Fort Kipp	33	330.6	150
Reserve	34	245.8	100
Medicine Lake	35	58.0	110
Coalridge	36	600.0	130
Lanark	37	100.0	120
Total		12,684.9	

1/ Numbers in this column refer to location on figure 1.
2/ Maximum intraburden between coalbeds where reserves are in multiple-beds.

report[2/] identified 618 million tons of coal in several areas of eastern Montana that could be strip mined by equipment available at that time.

Averitt[3/] presented the first detailed description of strippable coal reserves in eastern Montana in 1965, reporting 5.1 billion tons of strippable coal in 59 sites. His report, summarizing work of the U.S. Geological Survey in the eastern Montana coalfields, contains references to several other reports that identify strippable reserves. At the 1967 Lignite Symposium in Grand Forks, N. Dak., Groff (14)[4/] presented a paper describing 8.8 billion tons of coal contained in 31 major strippable deposits. The paper summarized information on areas possibly suitable for strip mining and included the results of joint drilling programs by the Montana Bureau of Mines and Geology and the Northern Pacific Railway Co., which delineated 3.8 billion tons of strippable coal in three coalfields. Additional sources of information that were used in this investigation are cited in the descriptions of strippable deposits.

GENERAL INFORMATION

Eastern Montana, a part of the Great Plains physiographic province, is an undulating mature upland, interrupted by low ridges and buttes and dissected by broad valleys of the easterly flowing Missouri and Yellowstone Rivers and their tributaries.

Steep slopes in the "breaks" along major rivers relieve the uniformity and monotony of the almost treeless plains. Another area of more rugged, even picturesque, topography is the clinker zone extending south of the Yellowstone River to the Wyoming border, where extensive burning of coalbeds has baked or fused overlying beds to an erosion resistant rock. These hardened beds form the protective caprock for many of the ridges and buttes in the area and are responsible for development of most of the sharper relief. Outcrops of clinker are usually light to dark red in color and contrast markedly with the somber colors of adjacent unbaked beds in the Fort Union Formation.

2/ Ford, Bacon & Davis, Inc. The Synthetic Liquid Fuel Potential of Montana, Oct. 31, 1951, 373 pp.

3/ Averitt, Paul. Coal deposits of eastern Montana, in Mineral potential of eastern Montana--A basis for future growth. U.S. 89th Cong., 1st sess., Senate Doc. 12, Feb. 2, 1965, pp. 9-25, 71-77 [repr. as Montana Bur. Mines and Geology Spec. Pub. 33, April 1965, pp. 9-25, 71-77; repr. in Montana Bur. Mines and Geology Spec. Pub. 36, March 1966, pp. 69-80].

4/ Underlined numbers in parentheses refer to items in the bibliography at the end of this report.

The northeastern part of the State has been glaciated, including the coal-stripping areas in Sheridan and Roosevelt Counties and the northern portions of Richland, McCone, and Dawson Counties. Bedrock surface was scoured and mantled with glacial debris. Former topographic features were modified and coal crops masked by till. Limited burning of the coal has occurred, and few clinker outcrops are found.

Open grass-covered plains are typical of eastern Montana. Trees are limited to scattered stands along stream and river valleys. In areas of more rugged topography, particularly the clinker areas, juniper and small ponderosa pine flourish on a scant rainfall.

The climate is semiarid and is characterized by long cold winters, by moderately warm to hot summers that have a wide diurnal range in temperature, and by irregular precipitation. Average annual precipitation is low, ranging from 10 to 15 inches. High winds, heavy snowfall, and subzero temperatures can be expected during winter months, but open pit coal mining is conducted year-around by following cold weather procedures.

Principal towns in eastern Montana are located on transcontinental highway and railroad routes. A low population density limits local consumption, and most products, primarily from agriculture, must be sold elsewhere. Only Miles City, Glendive, and Sidney can be classed as complete shopping centers.5/ Wolf Point, Circle, Forsyth, Hardin, and Broadus are partial shopping centers.6/ Wibaux and Colstrip have limited public facilities, and Decker has no services. Billings is the only primary wholesale-retail center in eastern Montana.7/

Interstate Route 94 follows the Yellowstone River valley northeasterly from Billings to the North Dakota boundary, and Interstate 90 connects Billings with Sheridan in northeastern Wyoming. The road net of eastern Montana includes several paved Federal and State high-

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5/ A complete shopping center has nine or more of the following retail functions: Sporting goods, family shoe store, florist, radio and TV store, tires-batteries-accessories, paint, glass and wallpaper, music store, children's wear, heating and plumbing equipment, antique or secondhand store, stationery, women's accessories, camera shop, and photographic studio.

6/ Partial shopping centers have four to eight of the retail functions listed in footnote 5.

7/ A primary wholesale-retail center has more than 100 wholesale establishments, and all of the following wholesale functions: Automotive supplies, bulk oil, chemicals and paint, drugs, dry goods, apparel, electrical goods, groceries and food, tobacco-beer, lumber and construction materials, hardware, industrial and farm machinery, paper, plumbing, heating, air-conditioning equipment, professional service equipment.

ways connecting with improved and unimproved county roads. Farm and ranch roads provide access to almost every stripping site, but such accessways are widely separated, and vehicular mobility within coalfields is limited.

Lines of four railroad companies serve eastern Montana. Haulage of coal from most of the strippable sites would require construction of spur lines.

Coal production for thermal power generation has replaced some of the production once required by the railroads before the advent of diesel-powered locomotives. Colstrip, Montana's largest strip coal mine, operated from 1923 to 1957 producing coal for the Northern Pacific Railway. A spur rail line connects the town of Colstrip with the mainline of the Northern Pacific Railway at Forsyth, and during the Northern Pacific mining operation trackage extended into the mining areas. Stripping was done by draglines, and coal was loaded directly into railroad cars by power shovels.

GENERAL GEOLOGY

The sedimentary rocks of eastern Montana were deposited in the western portion of the Williston Basin and northern portion of the Powder River basin. Williston is the largest known sedimentary basin on the North American continent. Together, the Williston Basin, in Montana, Wyoming, North Dakota, and South Dakota, and the Powder River basin of Montana and Wyoming contain 660 billion tons of coal within 3,000 feet of the surface. Within 6,000 feet of the surface, these States contain 1.455 trillion tons of coal[8/] and are ranked as one of the major coal areas of the world. Rocks of Paleocene age, comprising the Fort Union Formation, are distributed widely over eastern Montana and the adjacent States of Wyoming, North Dakota, and South Dakota. Where that formation is the bedrock, the area has been designated as the Fort Union region. All strippable coal deposits identified in this report are in the Fort Union region and are contained in the Tongue River Member of the Fort Union Formation. The Tongue River Member consists mainly of sandstone, shale, and numerous coalbeds. Locally this member contains carbonaceous shales, thin fresh-water limestone beds, and, on outcrops, clinker beds formed by burned coal. Except for minor variations, the coal-bearing rocks that enclose strippable deposits are essentially flat lying.

In northeastern Montana, the Tongue River Member is about 1,100 feet thick, and it becomes progressively thicker to the west and south.

8/ Averitt, Paul. Total Estimated Remaining Coal Reserves of the United States. U.S. Geol. Survey open file report. January 1, 1967, 1 p.

Much of the additional thickness can be attributed to an increase in the thickness and number of coalbeds, which also increase in rank on the same trend. About 1,500 feet of Tongue River sediments underlie portions of Big Horn and Powder River Counties, Mont. In these counties bordering Wyoming, the Wasatch Formation overlies the Tongue River Member and at higher elevations is the bedrock. A few coalbeds occur near the base of the Wasatch Formation. Thin coal is present in the Lebo, middle member, and Tullock, basal member, of the Fort Union Formation and in the underlying Hell Creek Formation of Cretaceous age. The Cretaceous rocks crop out along the western boundary of the Fort Union region, over the Cedar Creek anticline, and around the northern end of the Black Hills uplift (fig. 1).

Near the North Dakota boundary the lowest unit of the Fort Union Formation is the Ludlow Member, which contains a few thin beds of lignite. The Tongue River Member is the middle unit, and the upper unit is the Sentinel Butte Member. The Sentinel Butte and Ludlow Members are lithologically similar.

In the northeastern portion of the region, bedrock is masked by sheets of glacial debris. Scouring of the Fort Union by glacial ice and outwash has channeled the bedrock surface and removed portions of some coalbeds.

Unconsolidated glacial deposits of Quaternary age, mapped as the Flaxville gravel and lake deposits, overlie bedrock in the glaciated area. Elsewhere the surficial deposits include terrace deposits and alluvium.

Few natural outcrops of coal can be observed because much of the near-surface coal has burned, and extensive beds of clinker have been formed by baking of the overlying rocks. Outcrops of unburned beds are usually weathered, and only a dark band of coal bloom shows at the surface. Clinker, also called scoria or red shale, caps buttes, hills, and ridges, protecting these higher elevations against erosion.

Geologic structures in the Fort Union region are broad, gentle flexures of large size. The coalbeds and enclosing rocks are flat-lying or dip gently except for minor local steepening.

The rank of the Fort Union coal increases westward and southward from a 6,000-plus-Btu lignite in northeastern Montana to an average 9,720-Btu subbituminous coal in the Decker area near the Wyoming line on the west flank of the Powder River basin. As a general rule, seam thickness increases toward the southwest.

Individual and average analyses from a compilation[9/] published in 1967 for Montana coal or from more recent published and unpublished data

9/ Gilmour, Ernest H., and Gardar G. Dahl, Jr. Montana Coal Analyses. Montana Bureau of Mines and Geol. Spec. Pub. 43, 1967.

are included in this report with the description of each strippable deposit.

Except for undefined lignite deposits in Tertiary lakebeds in the southwestern part of the State, coalbeds in central and western Montana are geologically older, more disturbed by tectonic forces, and generally thinner than the coalbeds of the Fort Union region of eastern Montana.

STRIPPABLE COAL AREAS AND DEPOSITS

Strip coal mining costs depend upon such factors as overburden ratio, thickness and breakability of the overburden, character and thickness of the coalbed, and the production rate. Where conditions are favorable for strip mining, it is less costly than underground mining. Historically, the highest highwall carried at a Montana coal mine was at Colstrip. In 1950 the average thickness of overburden stripped at Colstrip was 85 feet (16). Equipment improvements have permitted a gradual increase in the overburden ratio and thickness that can be economically removed at an open pit coal mine.

After 10 years of inactivity the strip mine at Colstrip was reopened in July 1968 by a subsidiary of Consolidation Coal Co. and Montana Power Co. An annual production of about 500,000 tons of coal is shipped by rail to the Montana Power Co.'s Frank Bird power generation plant in Billings, Mont. South of Colstrip, Peabody Coal Co. is opening its Big Sky mine that will supply 2 million tons of coal per year by unit train to the Minnesota Power and Light Co.'s power generating plant at Cohasset, Minn. Since 1958 the Knife River Coal Mining Co., a subsidiary of the Montana-Dakota Utilities Co., has supplied about 300,000 tons of coal per year to the Lewis and Clark powerplant at Sidney. The coal is mined from a strip mine a few miles west of Savage. Big Horn Coal Co. strip mines coal for local consumption from a pit in the Decker area of Big Horn County.

The strippable coal deposits identified in this report are 5 or more feet thick, generally have less than 120 feet of overburden, and usually offer stripping ratios of less than 10 to 1. Stripping ratios are expressed as cubic yards of overburden to tons of coal.

Reserve estimates include total strippable coal and have not been reduced by a recoverability factor. Large blocks of coal that have been mined out, such as at Colstrip, have been excluded from the strippable areas and the reserve estimates, but the small amounts of coal removed from wagon mines have been ignored.

Where drill hole data were available on thick beds of coal the overburden limit was raised to as much as 200 feet. Outcrop data collected and published by the U.S. Geological Survey generally have

been conservative when compared to coal thicknesses disclosed by subsequent drilling. Outcrop measurements usually record less than the true coalbed thickness because of weathering and thinning at the outcrop, burning, or incomplete exposure of the full coalbed.

Projection of coalbeds for reserve estimates in the glaciated areas, hazardous because of inconsistencies in deposition, is further complicated by undefined glacial channels that have gouged out some near-surface coal. North of the Missouri River the only strippable reserves reported are those outlined by drilling.

For discussion purposes, the strippable coal deposits of eastern Montana have been grouped into ten areas that transgress the traditional coalfield outlines. From southwest to northeast in the Fort Union region, these are designated as the Decker, Birney-Broadus, Ashland-Coalwood, Colstrip-Brandenburg, Rosebud, Pine Hills, Wibaux, Richey-Lambert-Savage, southern McCone County, and Missouri River North areas.

Decker Area (1, 2)

Location and Geographic Features

The Decker area includes approximately 700 square miles in Tps 5-10 S, Rs 38-43 E, Rosebud and Big Horn Counties, Mont. The area is bordered on the south by the Montana-Wyoming State line, and the western perimeter is the outcrop edge of the coal-bearing Fort Union Formation. Northern and eastern boundaries are arbitrarily assigned.

Decker is a country postoffice and store near the west central part of the southern border. Sheridan, Wyo. (population 11,651), about 19 miles south of Decker via county road, is the nearest town of regional importance. The first mile of road from Decker to the State line has an improved gravel surface; from there to Sheridan it is paved. The several county roads across the coalfield are all unpaved, although most of them are of improved graded quality.

Surface elevations within the coalfield range from 4,800 feet along the Rosebud Creek-Tongue River divide in the southern part of T 6 S, R 39 E, to 3,100 feet along the Tongue River in the northeastern corner of the coalfield.

Near Decker structural dip approximates the topographic slope, resulting in relatively subdued relief. In its northeastward course, the Tongue River opposes the structural dip and therefore cuts across the rock strata. Thus, many thick coalbeds have been exposed, and extensive burning has occurred in the outcrop edges. Such burning left hard overlying clinker, which has resisted erosion. The result

has been the formation of steep-walled canyons having as much as 700 feet of relief in the northern part of the Decker area.

A main line of the Chicago, Burlington, and Quincy Railroad passes through Acme, Wyo., about 13 miles south of Decker, providing the nearest and most accessible rail facility.

Major local enterprises include stock raising and dry farming. Some valley bottoms are irrigated for better grass and hay production. Lumber for local use has been produced from pine and juniper timber growing on the uplands in the northern part of the coalfield.

Coalfield Geology

Stratigraphy

Some 300 to 500 feet of the Wasatch Formation is exposed in the Badger Mountains in the southern part of T 9 S, R 41 E. In this vicinity, there is no marked difference between the Wasatch and the underlying Tongue River Member of the Fort Union Formation. Both are composed of roughly equal parts of yellow sandstone and somber gray shales interbedded with coal. The Badger coalbed, about 375 feet above the top of the Roland coalbed that marks the base of the Wasatch, is the only coal of potential interest in this part of the section.

Underlying the Wasatch are 1,626 to 1,780 feet of sedimentary rocks assigned to the Tongue River Member that consists roughly of equal parts yellow sandstone and gray shale, plus at least 22 coalbeds of potential importance. The coalbeds are distributed through the entire section as indicated in table 2 (20, pp. 87-88).

The thick sandstone beds are persistent in neither the Wasatch nor the Tongue River, but they do form prominent ledges where they are present. Essentially all the coalbeds have burned along the outcrop.

Structural Geology

A broad southwestward-plunging syncline crosses the Decker coalfield. The bottom of the syncline is marked by several anticlines and synclines, all of low relief and all having long axes parallel to that of the main syncline. The Tongue River follows the approximate bottom of this syncline. The structure is essentially flat under the Badger Mountains. Farther east, in T 9 S, R 42 E, is another broad southerly-plunging syncline.

To the west, the beds reflect the Big Horn Mountains uplift. Structural dip on this side of the syncline is much more consistant. Total structural relief across the entire coalfield is a little over 1,000 feet.

TABLE 2. - Generalized Section of Wasatch Formation and Tongue River Member of Fort Union Formation in Eastern Big Horn County, Mont.

	Feet
Wasatch Formation:	
Badger bed	7
Interval	180
Local bed	5±
Interval	140
Local bed	5±
Interval	40
Tongue River Member of Fort Union Formation:	
Roland bed	0-13
Interval	195
Smith bed	7-20
Interval	70
Powers bed	0-10
Interval	60
Anderson bed	3-27
Interval	65
Dietz No. 1 bed	0-47
Interval	110
Dietz No. 2 bed	0-15
Interval	100
Dietz No. 3 bed	0-6
Interval	50
Canyon bed	6-24
Interval	180
Monarch bed	0-25
Interval	50
Davis, Carney, Wall, or Richard bed.	3-32
Interval	100
Carlson or Proctor bed	3
Interval	90
Brewster-Arnold, Sawyer, or R bed	0-20
Interval	50
Popham bed	3
Interval	175
Knoblock or Lee bed	0-20
Interval	60
Schoedel bed	0-14
Interval	40
Rosebud or Q bed	0-28
Interval	7-30
Holt or McKay bed	0-7

TABLE 2. - Generalized Section of Wasatch Formation and Tongue River Member of Fort Union Formation in Eastern Big Horn County, Mont.--Continued

	Feet
Tongue River Member of Fort Union Formation:	
Interval	50
Stocker Creek or P bed	0-9
Interval	35-50
Graham or O bed	0-7
Interval	30-65
N bed	0-7
Interval	25-40
Robinson, M, or Colman bed	0-23
Interval	43
Burley bed	0-5
Interval to base of Tongue River Member	130

Faulting is very difficult to recognize because of the extensive masking by burned coalbeds. Two small faults, of 22 and 35 feet displacement are reported in the literature. Two larger faults, having displacements of 180 and 220 feet, have been discovered through exploration drilling by coal companies. It seems likely that the Tongue River follows the course of the smaller of these two faults over part of its route through the southern part of the coalfield.

Additional faults probably will be found as the coalfield is further explored by drilling. Data available suggest that drag near faults may cause structural dips up to 17° or more, and coalbeds with dips this steep have been reported in the field. Such zones quickly flatten to dips of 3° or less. Normal dip is less than 1°.

Mining Considerations

Burned outcrops of the multiple coalbeds, stratigraphically close together, has resulted in rather extensive areas being covered by clinker. Often another coalbed, 10 or more feet thick, is found lying a few feet below the clinker. Thus clinker undoubtedly will be at least part of the overburden in any strip-mining operation. The remainder of the section should be relatively soft sandstone, siltstone, and shale.

The normally low structural dip (1° or less) should permit easy strip mine planning. Faulting will make planning and operation more difficult in some parts of the area, but such faults are likely to be rather widely spaced so that relatively little of the total area will be affected.

Correct correlation of coalbeds in the burned outcrop areas, especially where faulting also is involved, will be a major problem. Several good coal seams are only 10 to 60 feet apart. Without detailed planning based on exploration, the operator is likely to find unexpected seams of good coal but also may anticipate that some expected seams will be missing owing to burning, faulting, or lenticularity.

The multiple thick coalbeds in close stratigraphic proximity pose another mining problem. If multiple-bed stripping is planned, mining of three or more coalbeds could be accomplished over much of this area with relatively favorable stripping ratios. If single-bed stripping is used, rehandling of spoil piles to mine lower beds soon would create unfavorable stripping ratios.

Strippable Deposits

Location 1: Roland Deposit

The top of the Roland coalbed is considered to mark the base of the Wasatch Formation. This bed is the highest unit in the Tongue

River Member, and the coal is persistent under high divides in the southern half of the area.

The greatest measured thickness of the Roland bed is 13 feet at the John Bell mine in the SW1/4 sec 8, T 9 S, R 39 E. Mr. Bell reported that an additional 4 to 5 feet is left in the floor of his mine. To the north, the bed thins and pinches out in the vicinity of sec 22, T 8 S, R 42 E. As far east as Hanging Woman Creek the bed is 6 to 9 feet thick, but it seems to be absent east of the creek.

Topographic data are too poor to determine accurately the stripping areas; however, maximum recoverable reserves under less than 120 feet of overburden, have been estimated. This reserve is believed to average 6.8 feet in thickness, and should total 313.5 million tons (fig. 2). Coal analyses are not available, but the quality should be similar to the following proximate analysis of Roland coal from the Roland mine in sec 25, T 57 N, R 84 W, Sheridan County, Wyo.:

Form of analysis	Composition, percent[1/]					Heating value, Btu per lb
	Moisture	Volatile matter	Fixed carbon	Ash	Sulfur	
As received . . .	23.54	34.46	37.18	4.82	1.44	9,009
Air dried	17.87	37.01	39.94	5.18	1.55	9,677

1/ Taft, Joseph A. The Sheridan Coal Field, Wyoming. U.S. Geol. Survey Bull. 341, pt. 2, 1907, p. 136.

Location 2: Smith Deposits

The Smith coalbed has been definitely correlated with the Smith coal of the Sheridan field. In the Decker area, this bed underlies all topographically high areas. In the eastern part of the area, the outcrop edge near the Tongue River probably can be strip mined. Farther east the cover is too great; farther north the bed is too thin.

The thickest section is in the western part of the area. Near the north quarter corner of sec 4, T 9 S, R 39 E, the coal is reported to be 20 feet 4 inches thick. Although the bed thins farther north, it is commonly 7 to 10 feet thick.

The bed is thought to be strippable along the east sides of the hills west of Decker (fig. 3) and may possibly be strippable along part of the Rosebud Creek-Tongue River divide in the northwestern part of the area. The estimated strippable coal reserve in the area is 228.1 million tons under less than 120 feet of overburden. Quality should be comparable to coal in the Roland bed.

Location 3: Brewster-Arnold Deposit

The Brewster-Arnold coalbed (fig. 3) is exposed only in the northern part of the area. The bed tentatively has been correlated with the Sawyer bed of coalfields farther north. The estimated strippable coal reserve in the deposit is 71.2 million tons under less than 120 feet of overburden.

In the SE1/4 sec 29, T 6 S, R 42 E, 17 feet of the Brewster-Arnold bed is exposed, but its base is concealed below the level of the Tongue River. North of this locality the bed is usually 10 to 12 feet thick. A proximate analysis by the Bureau of Mines of the coal at the Brewster-Arnold mine in sec 23, T 6 S, R 42 E, follows (1):

Form of anaylsis	Composition, percent					Heating value, Btu per lb
	Moisture	Volatile matter	Fixed carbon	Ash	Sulfur	
As received . . .	27.3	28.9	39.2	4.6	0.6	8,850
Moisture free . .	-	39.8	53.9	6.3	.8	12,170
Moisture and ash free . . .	-	42.5	57.5	-	.9	12,990

Location 4: Anderson Deposits

The Anderson coalbed appears to be absent in the southwestern part of the Decker area. It thickens to the north and east to form one of the better reserves in the Decker field. In the northern half of the field where the bed has not been removed by erosion, it has been almost completely destroyed by burning, and clinker now caps the higher ridges. Unburned coal underlies the west slope of the divide between the Tongue River and Rosebud Creek and the divide between Tongue River and Hanging Woman Creek east of the Tongue River (fig. 4). Near its passage below stream level in First Creek, a tributary to Hanging Woman Creek, the coal is 27.5 feet thick. The estimated strippable coal reserve, using a 120 foot overburden limit, has been estimated at 300.8 million tons. No analyses have been published.

Location 5: Dietz Deposits West of the Tongue River

The Dietz No. 1 coalbed is extensively masked by clinker formed both by the burning of its own outcrop and those of overlying coalbeds. Early literature states that "this bed is thick for several miles north of the Wyoming-Montana State line, but is thin or absent under most of the northern half of the area." (1, pp. 35-36). Recent exploration drilling by coal companies suggest that the Dietz Nos. 1

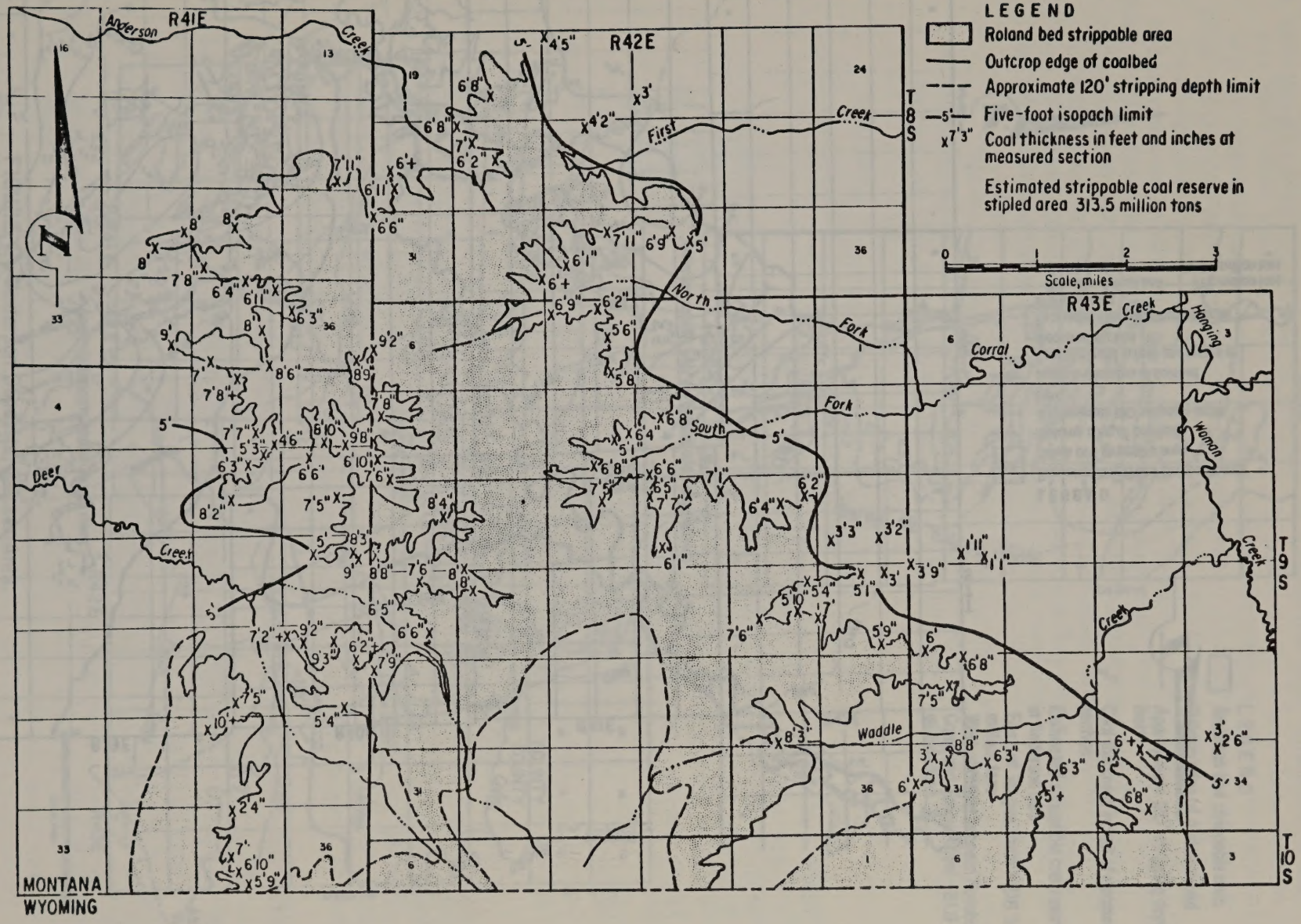

FIGURE 2. – Roland Deposit, Decker Area.
(Based on plate 29, U.S. Geol. Survey Bull. 806)

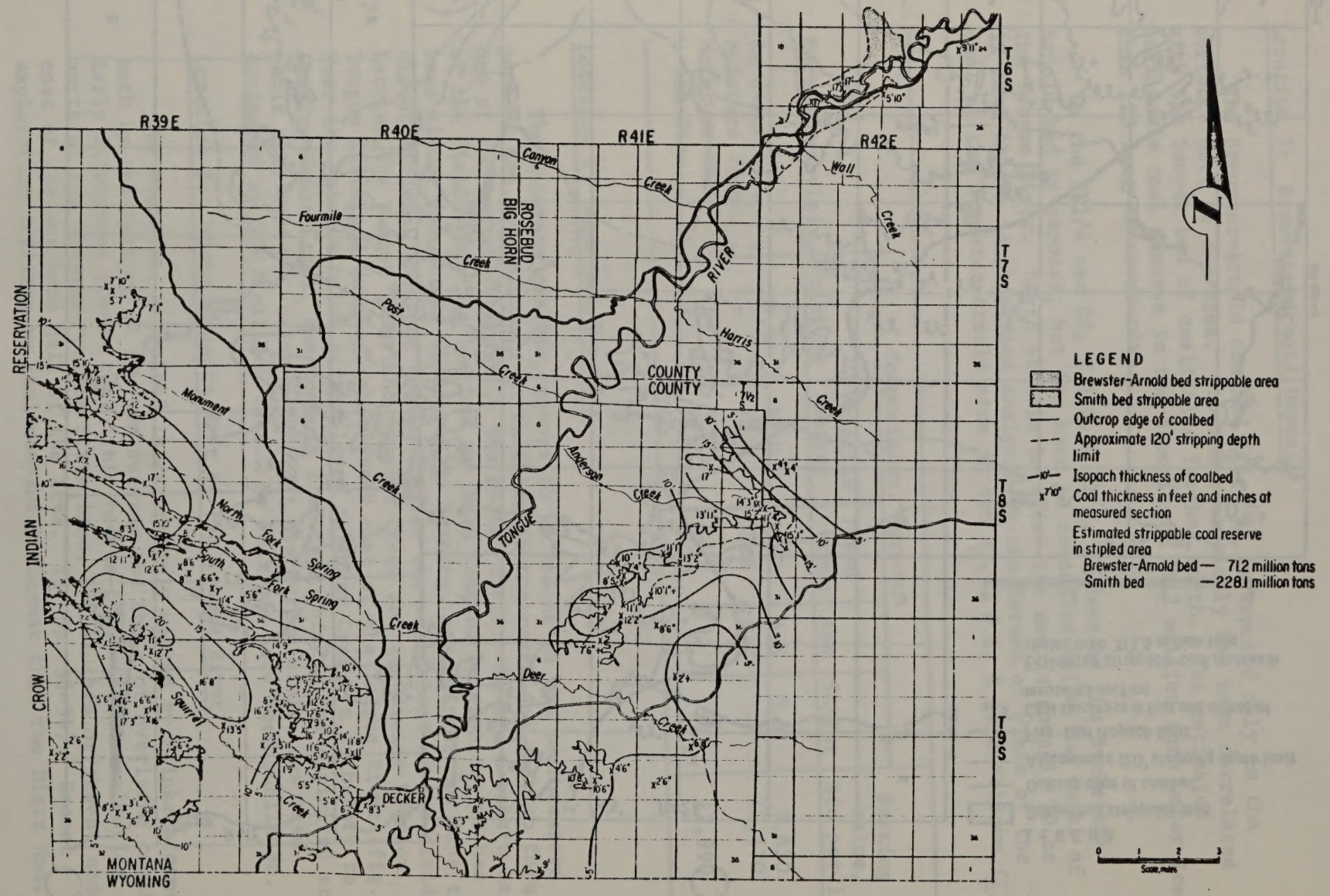

Figure 3. – Smith and Brewster–Arnold Deposits, Decker Area.
(Based on plates 28 and 29, U.S. Geol. Survey Bull. 806)

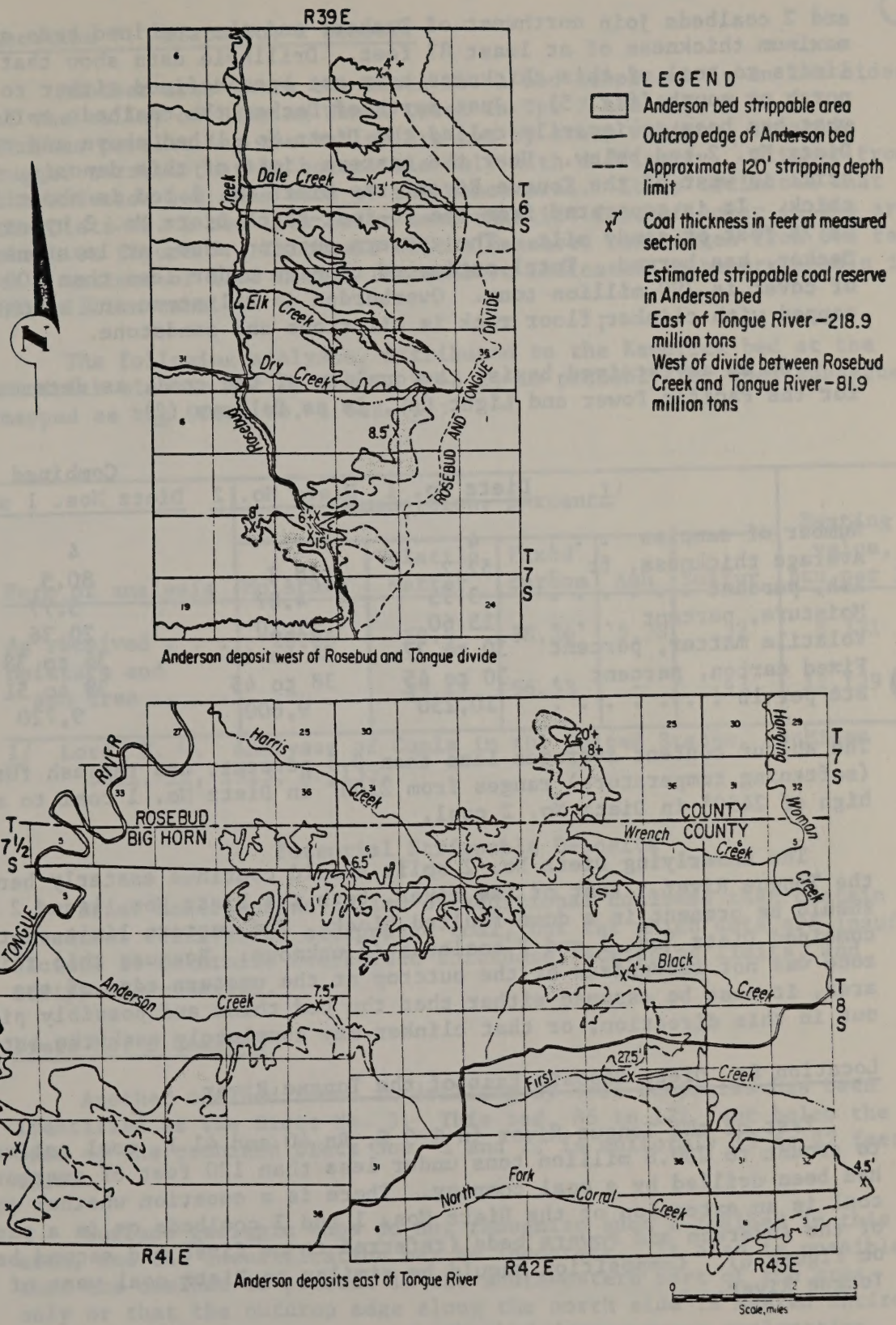

FIGURE 4. – Anderson Deposits, Decker Area.
(Based on plates 28 and 29, U.S. Geol. Survey Bull. 806)

and 2 coalbeds join northwest of Decker, and the combined beds attain a maximum thickness of at least 87 feet. Drillhole data show that the limits to coal of this thickness have not been defined either to the north or south (fig. 5). Just north of Decker the coalbeds split into what has been arbitrarily called the Dietz No. 1 bed above and the Dietz No. 2 bed below. Near the eastern limit of this deposit, which still is west of the Tongue River, the Dietz No. 1 bed is about 50 feet thick. It is separated from the 20-foot-thick Dietz No. 2 by as much as 76 feet of sandy silt. The eastern outcrop edge, at least near Decker, has burned. Total estimated tonnage under less than 200 feet of cover is 790 million tons. Overburden is siltstone and sandstone capped with clinker; floor rock is siltstone and sandstone.

On an as-received basis, the quality of the coal, as determined for the Pacific Power and Light Co., is as follows (2):

	Dietz No. 1	Dietz No. 2	Combined Dietz Nos. 1 and 2
Number of samples . . .	4	2	4
Average thickness, ft .	52.2	18.2	80.5
Ash, percent	3.95	4.87	3.77
Moisture, percent . . .	15.60	21.10	20.36
Volatile matter, percent	30 to 37	34 to 43	34 to 38
Fixed carbon, percent .	30 to 45	38 to 45	38 to 51
Btu per lb	10,250	9,600	9,720

The sulfur content averages less than 0.5 percent, and the ash fusion (softening temperature) ranges from 2100° in Dietz No. 1 coal to a high of 2450° in Dietz No. 2 coal.

The underlying Dietz No. 2 split should continue easterly beneath the Tongue River. East of the river, both the Dietz Nos. 1 and 2 beds should be present in a down-faulted block. The western limit of the combined Dietz Nos. 1 and 2 coalbeds is unknown. Because this thick zone was not recognized at the outcrop at the western edge of the area, it must be assumed either that the bed thins and possibly pinches out in this direction, or that clinker may completely mask the outcrop.

Location 6: Dietz Deposit East of the Tongue River

East of the Tongue River in T 9 S, Rs 40 and 41 E, coal estimated to amount to 230.8 million tons under less than 120 feet of overburden has been drilled by a coal company. There is a question whether this coal is an extension of the Dietz Nos. 1 and 2 coalbeds or is a part of the Anderson and Powers beds (referred to as first and second beds on figure 6). Composition should be similar to Dietz coal west of the Tongue River.

Location 7: Dietz No. 1 Deposit

Another area where the Dietz No. 1 bed crops out is on the sides of the valley of Hanging Woman Creek in Tps 7 and 8 S, R 43 E. Benches paralleling the valley are cut by steep ravines, creating rugged terrain that is accessible only with difficulty. Clinker from the Anderson bed caps much of the bench area. It is estimated that the Dietz No. 1 bed lies under less than 120 feet of cover in the area shown on figure 7. Thickness of the measured bed ranges from 6.2 feet to a maximum of 13.3 feet. The reserve indicated to be strippable is 331 million tons.

The following analysis, attributed to the Kendrick bed at the Kendrick mine in sec 2, T 8 S, R 43 E, is probably for coal subsequently mapped as the Dietz No. 1 bed (1):

Form of analysis	Composition, percent[1/]					Heating value, Btu per lb
	Moisture	Volatile matter	Fixed carbon	Ash	Sulfur	
As received . . .	28.86	29.5	38.36	3.28	.32	8,231
Moisture and ash free . . .	-	43.47	56.53	-	.47	12,129

1/ Lord, N. W. Analyses of Coals in the United States. BuMines Bull. 22, 1913, p. 135.

Potential Strippable Deposits

Brief descriptions follow of additional coalbeds that contain potential reserves of strippable coal, but for which data are insufficient to determine overburden thickness, stripping limits, and strippable reserves.

Dietz No. 3 Coalbed

Another coalbed found in drilling by coal companies has been identified as the Dietz No. 3. This bed, 86 to 121 feet below the base of the combined Dietz Nos. 1 and 2, is uniformly 19 to 22 feet thick.

Surface geologic maps do not recognize such a coalbed in this area, and the identification may be incorrect. It also is possible that the coalbed is present in the southwestern part of the area only or that the outcrop edge along the north side is masked entirely by clinker beds. In any event, the bed does warrant exploration.

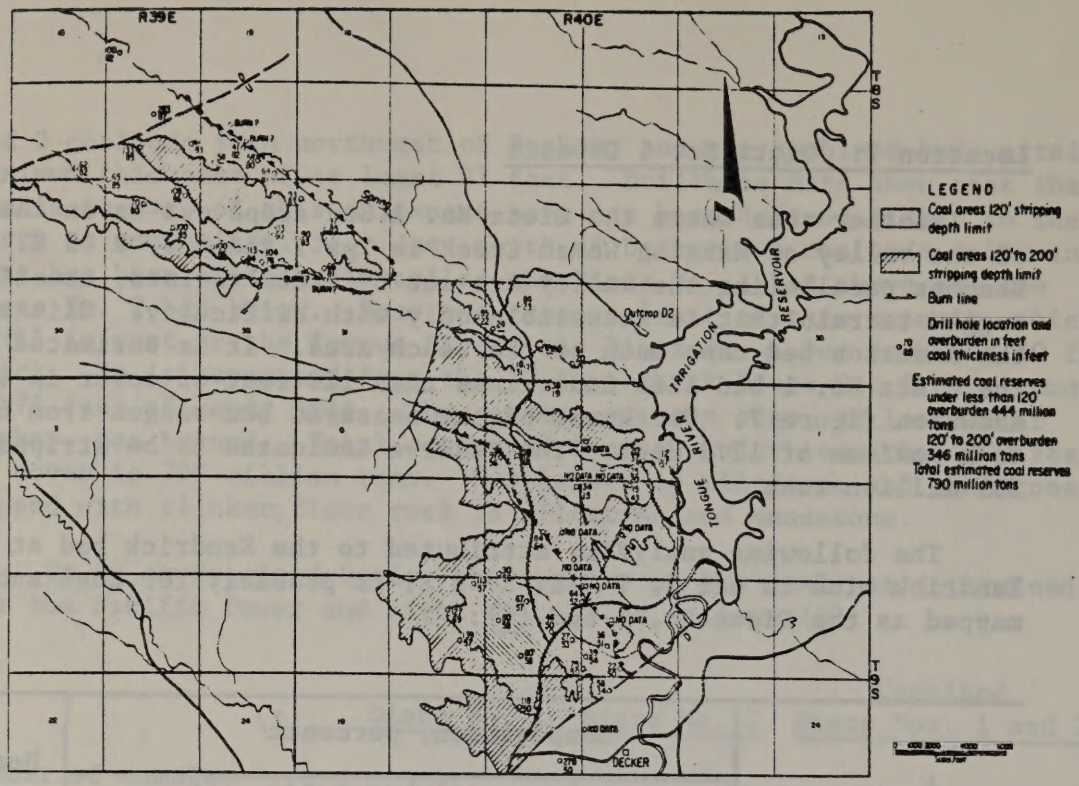

FIGURE 5. – Dietz Deposits West of the Tongue River, Decker Area.
(Based on company data)

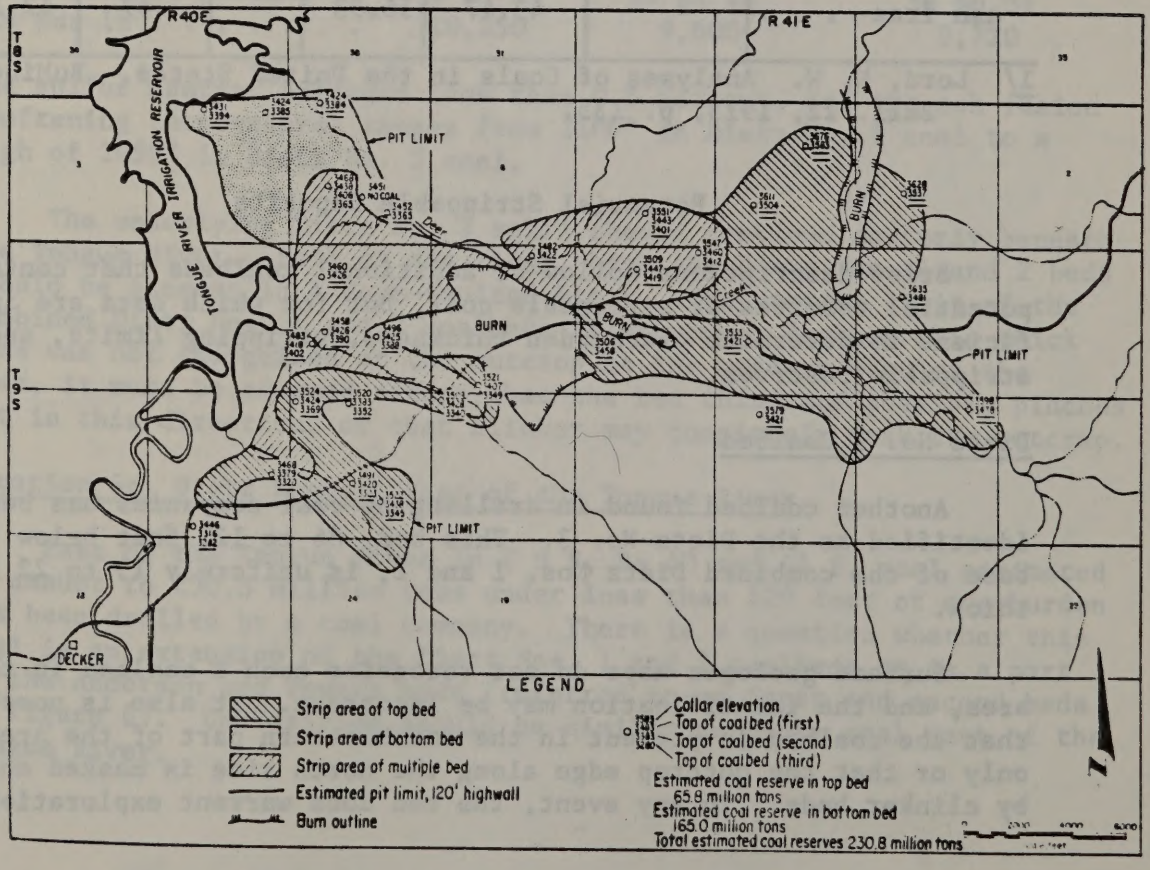

FIGURE 6. – Dietz Deposit East of the Tongue River, Decker Area.
(Based on company data)

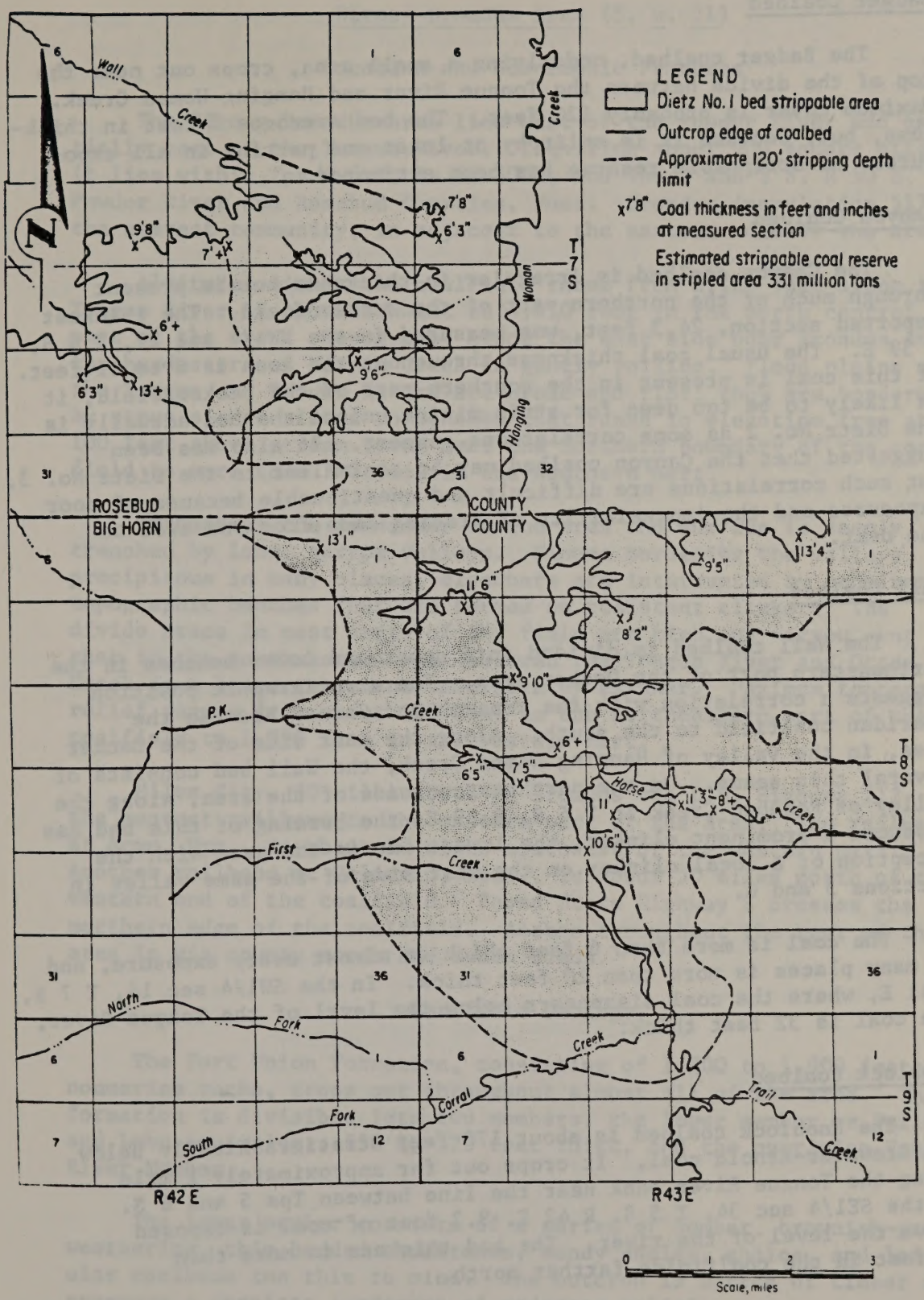

FIGURE 7. – Dietz No. 1 Deposit, along Hanging Woman Creek, Decker Area.
(Based on plate 29, U.S. Geol. Survey Bull. 806)

The Tongue River Member is composed of sandstone, sandy shale, shale, and coal. Yellowish-gray, massive, crossbedded sandstone, in beds as much as 100 feet thick, is found at different stratigraphic levels. It commonly weathers into cliffs, knobs, and pinnacles. Clinker caps prominent ridges, mesas, and buttes in most parts of the coalfield, and occurs in conspicuous bands along valley walls. The deeply dissected topography and relatively dense pine timber serve to contrast the Tongue River Member with the underlying lower member.

Structural dip in the northeastern part of the coalfield is about 20 feet per mile southwesterly. In the western part of the area, the dip is gently northwesterly. Local dips may be as much as 5°, but such dips are uncommon.

Mining Considerations

Except for clinker beds, there are no particularly hard zones in the Tongue River Member. Few if any clinker beds along outcrop edges of coal seams would be encountered during actual mining. Drilling and blasting may not be required prior to stripping, but actual needs should be determined accurately by preliminary exploratory drilling.

The flat-lying beds would be helpful to a mining operation. Rough topography will preclude production in much of the western part of the area. Lack of nearby railroad transport facilities is a major problem.

Coalbeds

Fifteen coalbeds are recognized in this coalfield. In addition there are a number of local beds. Briefly described, the named coalbeds, listed from top to bottom, are as follows:

Garfield bed: The Garfield bed, highest in the section and usually burned, consists of two benches about 60 feet apart. The upper bench ranges in thickness from 5 to 16 feet; the lower bench is 18 feet thick at one locality.

Alderson bed: The Alderson bed is always less than 5 feet thick and of small areal extent.

Canyon bed: Canyon bed is often split into two benches 45 to 55 feet apart. Each bench is locally 10 feet thick. The bed is usually more than 5 feet thick; maximum measured section is 13 feet.

Ferry bed: The Ferry bed is composed of discontinuous lenses usually less than 10 feet thick. Maximum measured thickness is 12.5 feet.

Cook bed: Cook bed includes two benches 40 to 75 feet apart in Tps 4 and 5 S, Rs 47 and 48 E. The bed is more than 10 feet thick in much of the area; maximum thickness is 25 feet.

Wall bed: Most measured sections of the Wall bed are 5 feet or more thick and many are 10 feet or more. The maximum measured thickness is 20.25 feet.

Elk bed: Elk bed includes discontinuous lenses usually less than 5 feet thick. Maximum thickness is 12.7 feet.

Dunning bed: The Dunning bed is more than 5 feet thick in many places. Maximum measured thickness is 16.5 feet.

Pawnee bed: The Pawnee bed is thickest in the eastern part of the field where it is 10 feet or more thick in many places. Its maximum measured thickness is 21.75 feet. In the northern part of the area, the bed is split into two benches as much as 45 feet apart. The upper bench may be the Dunning bed described above.

Odell bed: In T 5 S, Rs 45 and 46 E, the Odell bed averages 6 feet thick; maximum thickness is 11.5 feet.

Cache bed: Cache bed is often split into two benches 1.5 to 14 feet apart. Maximum thickness of the upper bed is 8.9 feet and of the lower bed, about 5 feet.

Sawyer bed: The Sawyer bed includes three lenticular benches 30 to 40 feet apart. The maximum thickness of the upper bench is 3.2 feet, the middle bench 10.25 feet, and the lower bench 5 feet.

King bed: Throughout most of its extent the King bed is less than 5 feet thick. The bed is thickest in T 5 S, R 43 E, where it is divided into two benches 20 to 35 feet apart. In secs 7 and 17 of this township the upper bench is as much as 10 feet thick, including 1.7 feet of partings. The lower bench in sec 18 of the same township is 7.75 feet thick.

Knoblock bed: Exposures of Knoblock bed are rare because of extensive burning of outcrops. At least in part of the area, the bed is divided into two benches 20 to 22 feet apart. Maximum known thickness of the upper bench is 12 feet and of the lower bench 16 feet.

Broadus bed: The Broadus bed ranges in thickness from 6.5 to 26.0 feet. In general it is thickest near the north boundary of the area.

Strippable Deposits

Location 8: Broadus Deposits

Two local lignite beds lie above the Broadus bed within part of the larger strippable area indicated on figure 8. The lower local bed is approximately 150 feet above the Broadus bed. Where the local lignite is not present, the regional Cache and Sawyer beds, in their respective areas, are approximately 300 feet above the Broadus bed. To establish the strip limit for the larger area shown on figure 8, the outcrop of the local bed was used where it is present. Throughout the remainder of the larger area the limit was assumed to be half way between the Broadus and the Cache or Sawyer traces, which infers a highwall limit of approximately 150 feet. Employing limits as described, the total estimated strippable area includes 34.4 square miles. Available measured sections indicate a probable average coal thickness of 10.75 feet. The estimated total original reserve in this part of the Broadus bed is 425.8 million tons.

Data from wide spaced drilling by the Northern Pacific Railway Co. and mapping by the U.S. Geological Survey (5) has been combined to define the possible strip area outlined in Tps 2 and 3 S, R 50 E, the smaller area on figure 8. The merged but still limited data indicate that the coal ranges in thickness from 7 to 26 feet. Because useful data are scarce, an arbitrary average bed thickness of 10 feet has been assumed. On this basis the indicated block,

covering 4.15 square miles, contains 47.8 million tons of coal under less than 120 feet of cover.

The 14-to-1 maximum stripping ratio inferred results from using a conservative coal thickness for reserve calculations. A joint drilling project by the Montana Bureau of Mines and Geology and the Northern Pacific has shown that the Broadus coalbed in the Broadus deposit is about 20 feet thick in 30 contiguous square miles and that about .5 billion tons would be strippable.

High and low values for Bureau of Mines analyses of coal from four mines in the Broadus coalbed are given in table 3.

TABLE 3. - Range of composition for coal in Broadus deposit (21)

Limits	Form of analysis[1/]	Moisture	Volatile matter	Fixed carbon	Ash	Sulfur	Heating value Btu/lb
High	A	33.9	31.6	33.1	8.1	0.4	7,380
	B	-	44.5	50.1	11.4	.6	10,970
	C	-	50.2	55.5	-	.6	12,130
Low	A	29.0	26.6	31.3	6.0	0.2	6,390
	B	-	40.2	44.1	9.0	.3	9,010
	C	-	44.5	49.8	-	.4	10,160

1/ A, as-received; B, moisture-free; C, moisture- and ash-free.

Location 9: Knoblock Deposits

Within the areas indicated to be strippable on figure 9, the King coalbed is 65 to 200 feet above the Knoblock bed. Because detailed data on the stratigraphic interval between the two beds are not available, it was assumed that the interval averages about 130 feet throughout the area indicated. In part of the area, the depth to the Knoblock bed will exceed 130 feet requiring a drawback of estimated strip limits. In other parts of the area, the stripping depth at the limit indicated should be less than the estimated 130 feet, permitting an increase in the proposed strip area. Such area adjustments should be compensating, thus providing a degree of reasonableness to the estimates that follow.

The potentially strippable deposits indicated on figure 9 cover 31.8 square miles and contain a total coal reserve of 494.9 million tons. Based on published measurements the average thickness of the Knoblock bed within these areas is 13.5 feet but probably is

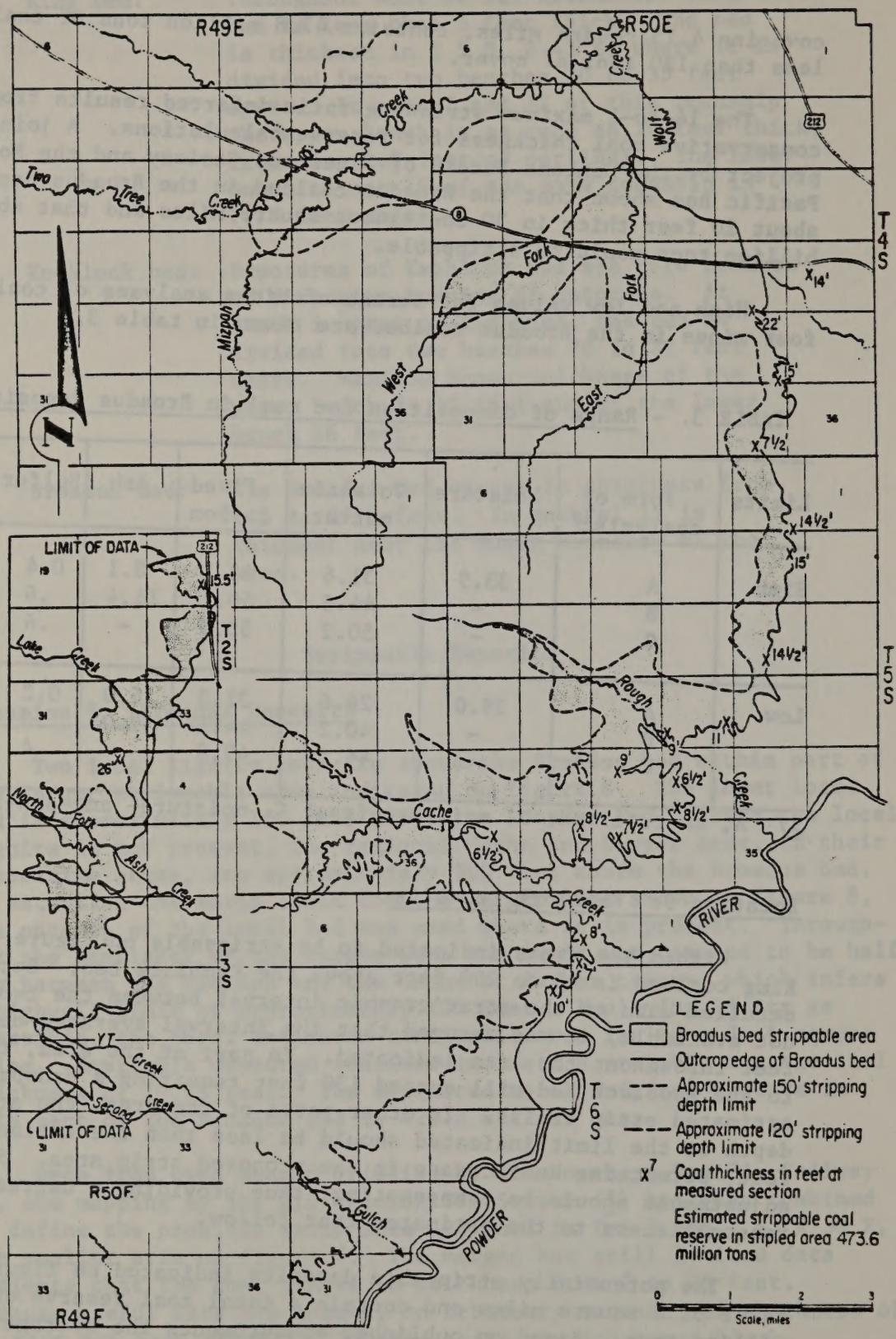

FIGURE 8. – Broadus Deposits, Birney–Broadus Area. (Based on plate 19, U.S. Geol. Survey Bull. 1072J and plate 1, U.S. Geol. Survey Bull. 973B)

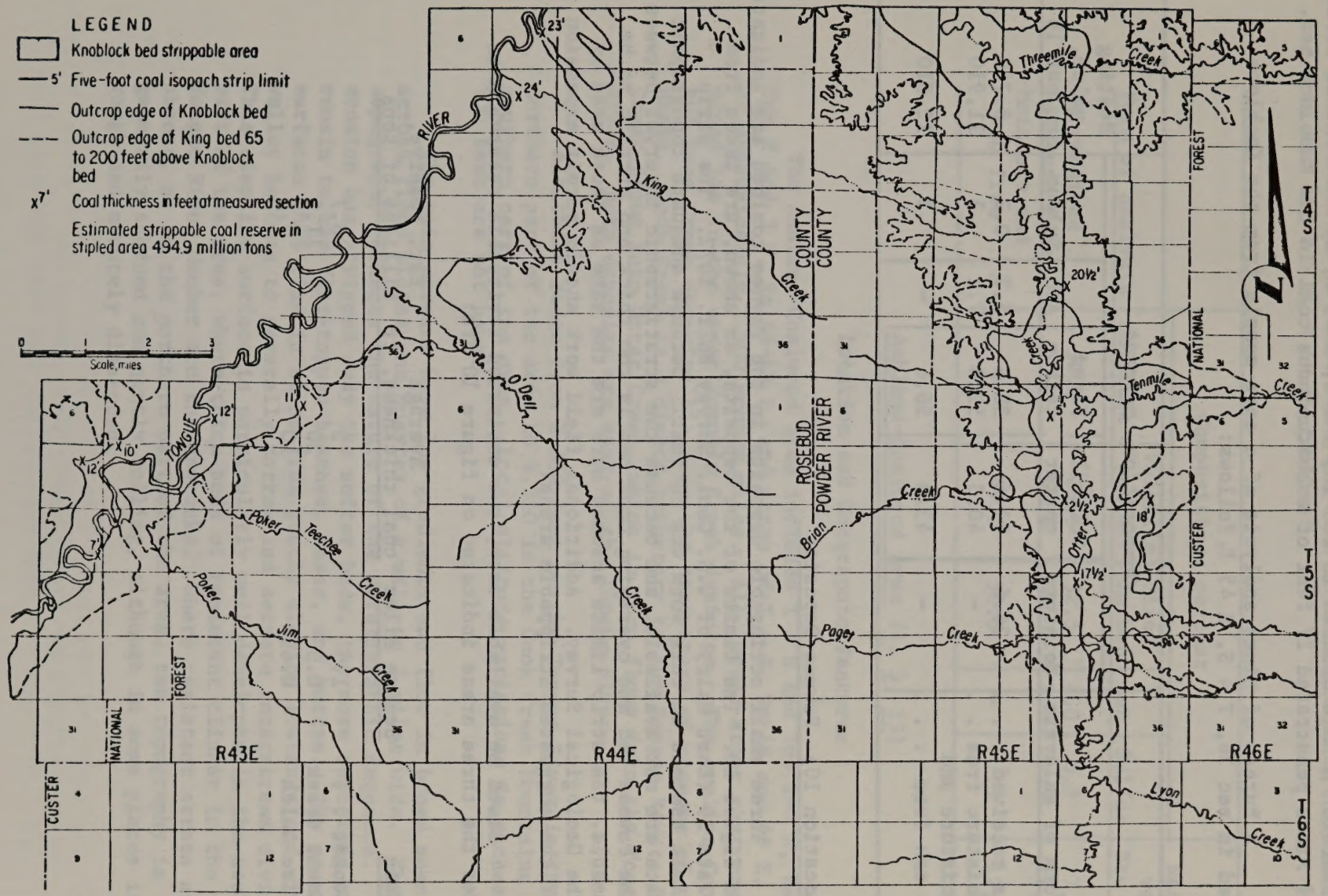

FIGURE 9. – Knoblock Deposits, Birney–Broadus Area.
(Based on plate 19, U.S. Geol. Survey Bull. 1072J)

greater. A hole drilled in sec 16, T 5 S, R 43 E, by the Montana Bureau of Mines penetrated 27 feet of subbituminous coal in the Knoblock bed.

A Bureau of Mines analysis of a core sample from the Knoblock bed in sec 36, T 4 S, R 45 E, follows:

Form of anlaysis	Composition, percent					Heating value, Btu per lb
	Moisture	Volatile matter	Fixed carbon	Ash	Sulfur	
As received . . .	26.6	29.6	38.6	5.2	0.2	8,740
Moisture free . .	-	40.3	52.6	7.1	.3	11,910
Moisture and ash free . . .	-	43.3	56.6	-	.3	12,810

Location 10: Pawnee Deposits

Three small strippable deposits in the Pawnee coalbed are indicated on figure 10. The limits of the deposits, as shown, are taken from Plate 19 (East Half) of U.S. Geol. Survey Bull. 1072. The strip limit assumed in this work was 50 feet. Because adequate topographic data are not available, and because the stratigraphic interval between the Pawnee bed and overlying Cook bed is too thick and erratic to be usable, the strip limits assumed here are the same as those used by the Geological Survey. Additional field work should permit expansion of the suggested strippable areas.

Based on available data, the estimated strippable reserve data for the three areas indicated on figure 10 are:

Name	Square miles	Average coal thickness, ft	Est. reserve, millions of tons
Sonnet . .	1.5	5	8.7
Cache Creek	0.5	20	11.5
Fire Gulch	0.65	10	7.5

A Bureau of Mines analysis of a core sample from the Pawnee bed in sec 36, T 5 S, R 48 E, follows:

Form of analysis	Composition, percent					Heating value, Btu per lb
	Moisture	Volatile matter	Fixed carbon	Ash	Sulfur	
As received . . .	32.0	29.5	32.5	6.0	0.2	7,650
Moisture free . .	-	43.4	47.8	8.8	.3	11,250
Moisture and ash free . . .	-	47.5	52.5	-	.3	12,340

Ashland-Coalwood Area (4, 5, 15)

Location and Geographic Features

The Ashland-Coalwood area includes T 1 S and Tps 1-4 N, Rs 45-50 E, Tps 2 and 3 S, Rs 45-49 E, and parts of T 4 S, Rs 48 and 49 E, an area of approximately 1,500 square miles. All larger areas that may be strip mined lie in the upper Pumpkin Creek drainage. The smaller Cook Creek and Home Creek deposits lie near the headwaters of streams of the same names. Cook Creek is a direct tributary to the Tongue River; Home Creek flows into Otter Creek, which in turn flows into the Tongue River. Both deposits are east of the Tongue River.

Altitudes range from 2,500 feet on the Tongue River in the northern part of the area to 4,350 in the Cook Creek Mountains in the southern part of the area. Local altitude variations in excess of 500 feet are not usual.

The main streams have low gradients and flow in broad meanders across flood plains one quarter of a mile to 2 miles wide. The topography reflects the nature of the stratigraphic sequence. Where erosion has stripped away the softer beds, the more resistant strata remain to cap flat-topped benches, mesas, and buttes. The resulting surfaces thus rise in steps from gently sloping lowlands and wide valley bottoms to generally narrow and serrate interstream divides. This steplike surface is particularly well developed in the southern part of the area, where thick beds of resistant clinker in the Tongue River Member are the caprocks. Where resistant strata are absent, as in the northern part of the area, the topography is generally subdued and gently rolling, although in some places it is rough and minutely dissected.

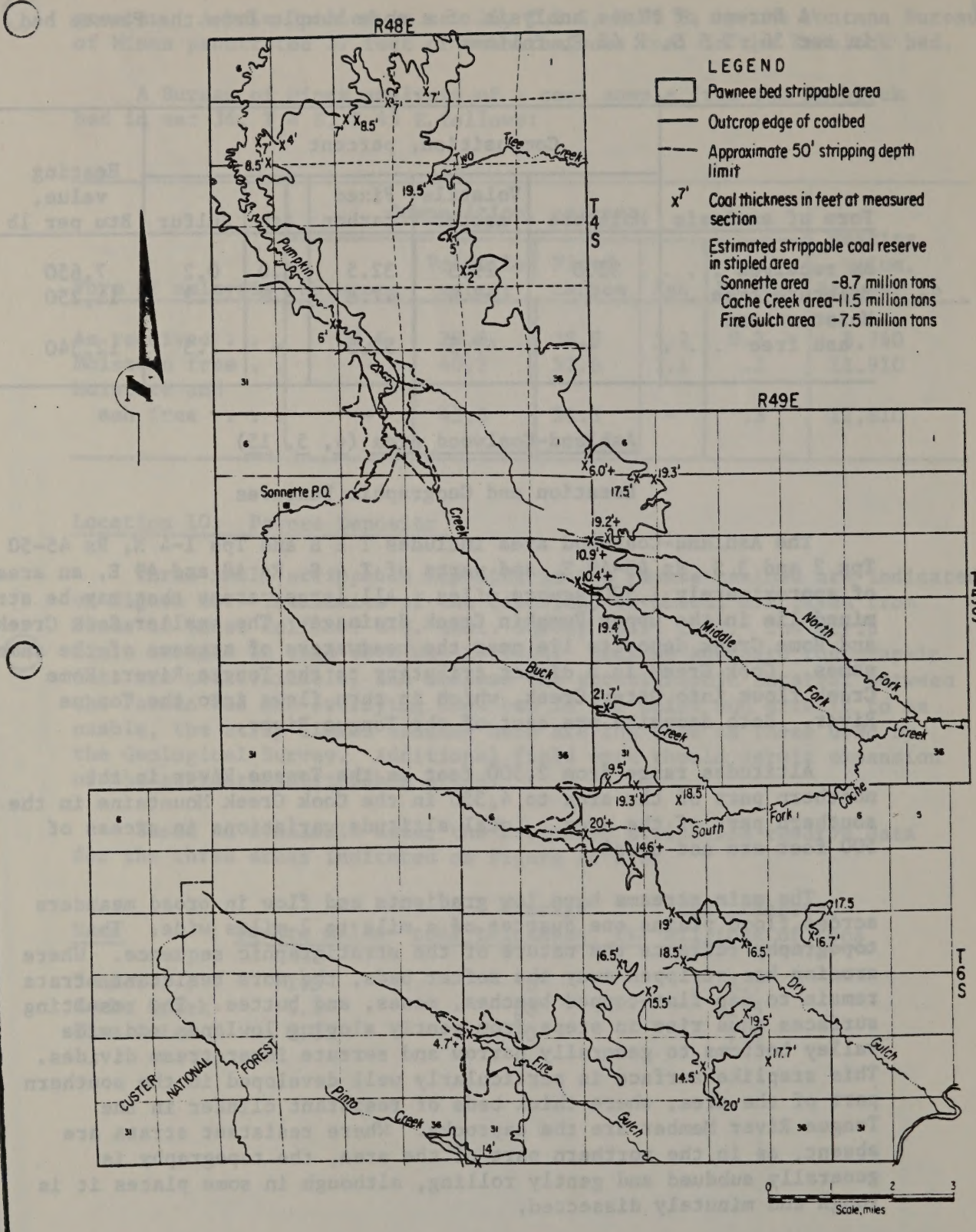

FIGURE 10. – Pawnee Deposits, Birney–Broadus Area.
(Based on plate 19, U.S. Geol. Survey Bull. 1072J)

Miles City (population 9,243), the county seat of Custer County, is approximately 45 miles north of the central part of the Ashland-Coalwood area. Access is via paved U.S. Highway 212. Ashland (population 120) in the southwestern corner of the area is the only settlement with more than a post office-general store combination.

U.S. Highway 212 passes north-south across the eastern part of this area. State Highway 8 crosses the southern edge. The remainder of the area is served by several graded county roads and unpaved ranch roads. During wet weather only the surfaced roads are passable.

Main lines of both the Northern Pacific Railway and the Milwaukee Road pass through Miles City paralleling the Yellowstone River. There are no spurs to the south except to Colstrip, which lies about 35 miles west of the western limits of this area. The gentle gradient and open country would permit easy track laying if rail transport becomes desirable.

Coalfield Geology

The two upper members of the Fort Union Formation, the Lebo and the Tongue River, are exposed in the Ashland-Coalwood area. The lower or Lebo Member, about 170 feet thick, is exposed in the northern part of the area and along the major drainage bottoms. The overlying Tongue River Member, a maximum of 1,600 feet thick in the Cook Creek Mountains, is exposed throughout the remainder of the area.

The Lebo consists of soft clay and shale that weathers to a dull yellow or dark gray and contains thin coalbeds of negligible value. It supports little or no vegetation and erodes easily to produce low rounded hills and spectacular badlands.

The Tongue River Member is composed of sandstone, shale, sandy shale, thick coalbeds, and a few thin limestone beds. Extensive masses of pink, red, or brown clinker normally cap ridge tops, and are the most diagnostic characteristic of the member. Rugged land forms of marked relief are common because of the prevalence of resistant clinker, limestone, and massive sandstone overlying soft, easily eroded beds of sandstone and shale. East of Pumpkin Creek the more resistant beds are absent, resulting in a gently rolling land surface.

Remnants of terrace gravel deposits lie along the valleys, particularly the west side of the major streams. Most of these deposits are less than 300 feet above the present stream level in the southern part of the area.

The Tongue River follows the axis of a broad, shallow syncline. Therefore, rocks of this area, which form part of the southeast flank of the syncline, dip a few tens of feet per mile northwesterly. The

slight inclination is not apparent to the unaided eye. The slight faulting of the area does not affect any of the suggested strip mine areas.

Mining Considerations

The essentially flat-lying beds and lack of faulting materially simplify strip mining. In the northern and eastern parts of the area, away from the rugged topography resulting from the presence of the more resistant beds, coal probably can be stripped without the aid of blasting. In the more southerly and westerly areas, blasting prior to stripping may be required.

Coalbeds

Nine coalbeds are recognized in the lower part of the Tongue River Member of the Fort Union Formation. Four beds, the Terret, Flowers-Goodale, Knoblock, and Sawyer, listed in sequence from the lowest, are strippable in parts of the Ashland-Coalwood area.

The Terret bed, one of the thinner strippable deposits, ranges from 6 to 12 feet thick over most of the area and averages about 8 feet. The maximum observed thickness is 13.3 feet. The bed thins eastward and abruptly pinches out east of Pumpkin Creek. Measurements west of the Tongue River show that toward the northwest the bed splits into several thin benches not suitable for mining. The interval between the Terret bed and the base of the Tongue River Member decreases eastward from 160 feet west of the Tongue River to about 70 feet east of Pumpkin Creek.

The Flowers-Goodale bed is 60 to 120 feet above the Terret bed. It is in approximately the same stratigraphic position as the Rosebud bed of the Rosebud coalfield to the west, and the Broadus bed of the Coalwood field to the east. The bed ranges from 2 to 12 feet thick and probably averages about 8 feet.

Thickness of the Knoblock bed ranges from 2 feet at its eastern outcrop on the Pumpkin Creek-Mizpah Creek divide to 26 feet just east of the Tongue River. Well logs suggest that it attains a thickness of 40 feet in the extreme southwestern part of the area. The bed probably averages from 10 to 15 feet thick along its entire outcrop. The Knoblock bed lies 55 to 140 feet above the Flowers-Goodale bed, the interval thinning from west to east. A lower bench, 35 to 60 feet below the main upper bench, is not included in these figures.

The stratigraphic interval between the Sawyer bed and the underlying Knoblock bed thins eastward from 300 feet in the Cook Creek Mountains to 135 feet just east of Pumpkin Creek. Maximum measured thickness of the Sawyer bed is 36 feet. The bed exceeds 15 feet over two fairly large areas, one centered in T 2 S, R 45 E, and the other

in T 3 S, R 49 E. Exposures of the Sawyer bed are few and widely scattered, most of them occurring where the bed is less than 10 feet thick. The outcrop at thicker locations is masked by extensive clinker.

Strippable Deposits

Location 11: Cook Creek Deposit

The Sawyer coalbed lies under less than 120 feet of cover within the area designated on figure 11. The measured bed thickness ranges from 4.5 feet, in incomplete sections, to a maximum of 12 feet. It is probable that the bed averages 9 feet thick in the strippable area. Coal under less than 30 feet of cover has been excluded from consideration because of extensive erosion and probable extensive weathering. The original reserve in the area indicated to be strippable on figure 11 is 17.6 million short tons. Additional reserves of 16.7 million tons may underlie that area indicated as probably strippable.

Clay lies immediately above and below the coalbed. The lower 50 feet of overburden consists of about two-thirds soft shale and one-third soft, fine-grained sandstone. The next 70 feet consists of a soft, fine- to medium-grained sandstone interbedded with a few thin beds of hard, flaggy, ferruginous sandstone.

Location 12: Cottonwood Creek Deposit

The Knoblock coalbed of the Cottonwood area is consistently 14 to 15 feet thick and has no partings. It is assumed, therefore, that the average thickness of coal in this deposit is 14 feet. On this basis, the strippable reserve under less than 120 feet, as indicated in figure 11, is estimated to be 27.7 million tons. The additional area indicated on the same figure as probably being strippable could add 13.0 million tons to the coal reserve potential.

A core sample taken from the Knoblock bed in sec 29, T 1 S, R 48 E, was analyzed by the Bureau of Mines with the following results:

Form of analysis	Composition, percent					Heating value, Btu per lb
	Moisture	Volatile matter	Fixed carbon	Ash	Sulfur	
As received . . .	33.1	27.1	33.1	6.7	0.4	7,380
Moisture free . .	-	40.5	49.5	10.0	.6	11,040
Moisture and ash free . . .	-	45.0	55.0	-	.6	12,260

The Knoblock coal is underlain by gray shale. The overburden consists of porous, massive, soft, medium-grained sandstone that is interbedded with some shale. From 60 to 130 feet above the coal, the sandstone contains a few calcareous concretions and thin beds of more resistant sandstone.

Location 13: Home Creek Deposit

The Sawyer coalbed can be strip-mined in the Home Creek area. Measurements on incomplete coal sections range from about 5 feet to 16.3 feet.

The deposit is thought to average about 8 feet thick, but the coal thins in a general southeastward direction. This is the reason for limiting the suggested strippable reserve as indicated on figure 11. Strippable coal is estimated to total 41.1 million tons under less than 120 feet of cover.

Sawyer coal lies on clay. The lower 50 feet of overburden is shale and fine-grained sandstone; that above is largely siltstone and poorly consolidated sandstone. Local concentrations of calcareous cement and ferruginous or calcareous concretions are found in the sandstones.

Location 14: Foster Creek Deposit

Both the Foster Creek and Sand Creek deposits are included on figure 12, the larger Foster Creek deposit to the west and the Sand Creek deposit to the east. Erosion has exposed outcrop edges of the Terret, Flowers-Goodale, and Knoblock coalbeds in the Foster Creek area. All three beds would provide extensive strippable reserves if mined only to a depth limit of about 120 feet. However, the stratigraphic interval between beds is such that multiple-bed stripping and mining, if carried on simultaneously, should be economically feasible.

Within the Foster Creek district, the lowest bed, the Terret, ranges from 6 to 16 feet thick and averages 8.4 feet. Available data suggest a possible thickening of the bed to the south, perhaps continuing under the other strippable coalbeds. Exploration of the area should test this potential. The strippable reserve from the Terret bed outcrop back to the outcrop edge of the Flowers-Goodale bed, where the Terret reaches a depth of 100 to 120 feet, is 353.6 million tons. If the Terret bed averages 9 feet under the proposed Flowers-Goodale and Knoblock stripping areas, an additional 406.4 million tons should be available, assuming that multiple-bed stripping is employed. The stratigraphic section between the Terret coalbed and the overlying Flowers-Goodale coalbed consists of soft sandstone and shale, in equal amounts, and one thin lenticular bed of limestone.

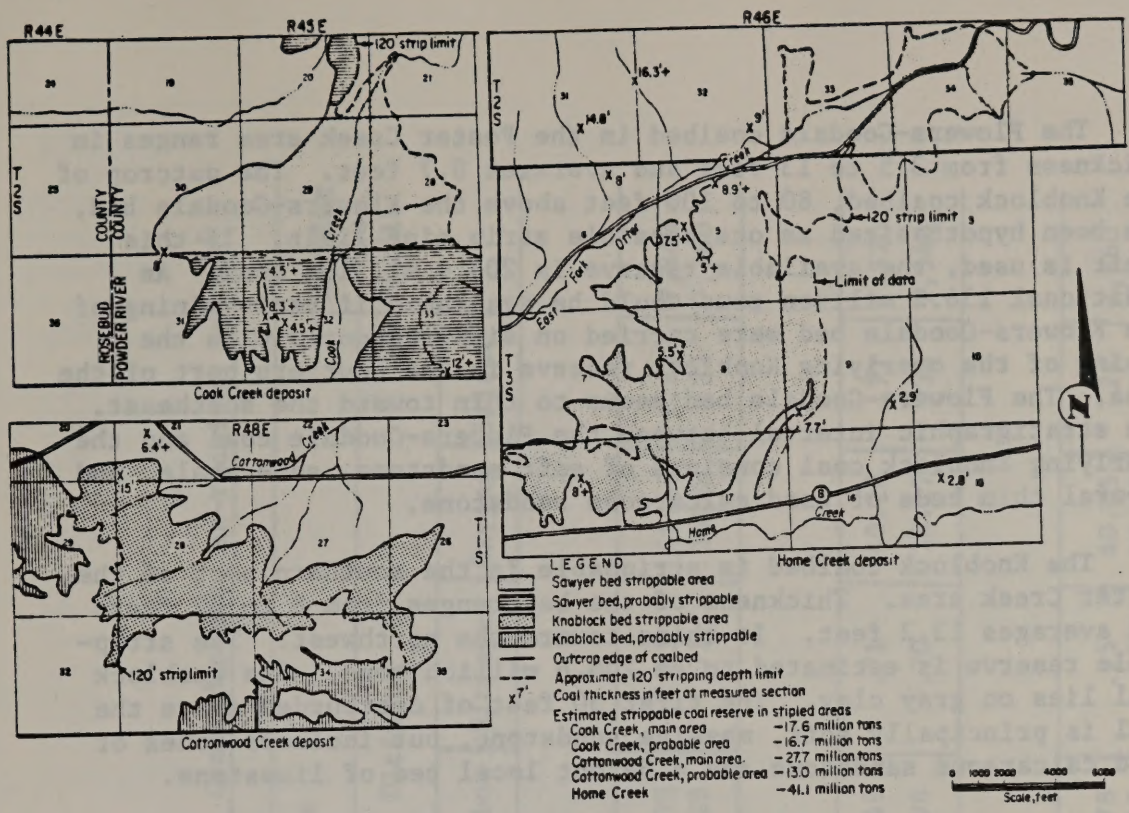

FIGURE 11. – Cook Creek, Home Creek, and Cottonwood Creek Deposits, Ashland–Coalwood Area. (Based on figures 23, 26, and 28, U.S. Geol. Survey Bull. 995)

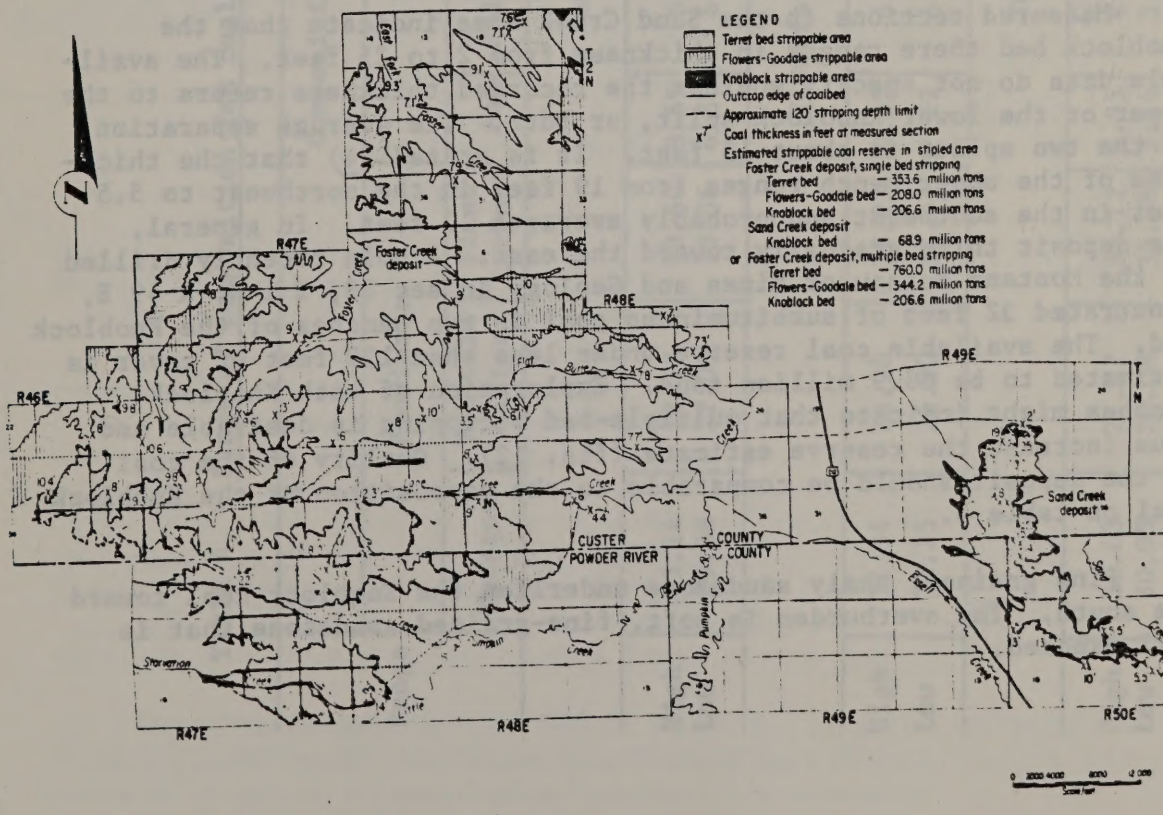

FIGURE 12. – Foster Creek and Sand Creek Deposits, Ashland–Coalwood Area. (Based on plates 22 and 23, U.S. Geol. Survey Bull. 995, and plate 1, U.S. Geol. Survey Bull. 973)

The Flowers-Goodale coalbed in the Foster Creek area ranges in thickness from 3.5 to 13 feet and averages 8.7 feet. The outcrop of the Knoblock coalbed, 80 to 100 feet above the Flowers-Goodale bed, has been hypothesized as one possible strip mine limit. If this limit is used, the available reserve is 208.0 million tons. An additional 136.2 million tons would be available if strip mining of the Flowers-Goodale bed were carried on simultaneously with the mining of the overlying Knoblock reserve in the southern part of the area. The Flowers-Goodale bed seems to thin toward the southeast. The stratigraphic interval between the Flowers-Goodale coal and the overlying Knoblock coal consists of soft sandstone, some shale, and several thin beds of hard calcareous sandstone.

The Knoblock coalbed is strippable in the southern part of the Foster Creek area. Thickness of the bed ranges from 8 to 22 feet and averages 13.2 feet. It thins toward the northwest. The strippable reserve is estimated to be 206.6 million tons. The Knoblock coal lies on gray clay. The first 50 feet of overburden above the coal is principally soft, massive sandstone, but includes zones of hard calcareous sandstone and a 5-foot local bed of limestone.

The range of composition for 3 samples from each coalbed are shown in table 4.

Location 15: Sand Creek Deposit

Measured sections in the Sand Creek area indicate that the Knoblock bed there ranges in thickness from 2 to 25 feet. The available data do not specify whether the recorded thickness refers to the upper or the lower Knoblock split, or both. The average separation of the two splits is about 15 feet. It is stated (4) that the thickness of the upper bench ranges from 19 feet in the northwest to 5.5 feet in the southeast and probably averages 12 feet. In general, the deposit thins gradually toward the east. A hole recently drilled by the Montana Bureau of Mines and Geology in sec 28, T 1 N, R 49 E, penetrated 32 feet of subbituminous coal in two benches of the Knoblock bed. The available coal reserve under less than 120 feet of cover is estimated to be 68.9 million tons. Exploration of both Knoblock benches might indicate that multiple-bed stripping is desirable and thus increase the reserve estimate (fig. 12). Quality of the coal in the deposit should be comparable to the composition of the Knoblock coal on table 4.

Fine grained, shaly sandstone underlies the Knoblock coal toward the south. The overburden is soft, fine-grained sandstone that is well exposed.

TABLE 4. - Range of composition for coal in Foster Creek deposit, as-received basis[1/]

Range	Composition, percent									Heating value, Btu/lb
	Proximate			Ultimate						
	Moisture	Volatile matter	Fixed carbon	Ash	Hydrogen	Carbon	Nitrogen	Oxygen	Sulfur	
Knoblock										
High	33.14	28.17	33.60	8.65	6.53	46.36	0.75	41.47	1.61	7,840
Low	29.58	27.09	33.06	6.66	6.35	44.29	.71	36.28	.32	7,380
Flowers-Goodale										
High	31.54	26.98	35.23	9.02	6.45	45.49	.71	40.26	.77	7,570
Low	30.25	26.20	34.11	7.27	6.26	44.96	.70	38.17	.36	7,540
Terret										
High	31.63	27.37	37.12	6.25	6.25	47.78	.75	40.45	.24	7,860
Low	30.05	26.58	35.38	5.14	5.11	46.16	.70	39.08	.20	7,630

1/ Data from U.S. Bureau of Mines, Grand Forks Coal Research Laboratory.

FIGURE 13. – Pumpkin Creek Deposit, Ashland–Coalwood Area. (Based on plate 1, The Pumpkin Creek Lignite Deposit, Powder River County, Montana, an unpublished report of the Northern Pacific Railway Co. by Virgil W. Carmichael)

Location 16: Pumpkin Creek Deposit

The Pumpkin Creek deposit has been reported by the U.S. Geological Survey (4) and explored by the Northern Pacific Railway Co. Based on the Northern Pacific project, Groff (14) published the gross features of the deposit and Virgil W. Carmichael submitted a detailed graduate thesis in May 1967 to the University of Idaho.

The Sawyer coalbed, ranging in thickness from 28 to 36 feet, is under less than 200 feet of overburden throughout most of the area indicated on figure 13. The Sawyer coalbed divides into two benches south of the line of split shown on figure 13, and further south into three benches. An estimate of 404 million tons of strippable coal for that part of the deposit south of the split line includes only the upper bench, averaging 16-1/2 feet in thickness, under less than 150 feet of overburden. North of the split line the strippable reserve is estimated to be 1,497 million tons under less than 200 feet of overburden; the bed averages 30 feet in thickness in the northeast part of the deposit and 32 feet in thickness in the northwest part. Thin coalbeds in the overburden are not included in the reserve.

Total strippable reserve in the deposit is 1,901 billion tons.

A breakdown of this reserve by overburden range follows:

Overburden range, ft	Strippable reserve, millions of tons
0 to 50	493
50 to 100	675
100 to 150	500
150 to 200	233

Six core samples from the Sawyer coalbed were analyzed for the Northern Pacific Railway Co. and the results are shown in table 5.

The Sawyer bed is underlain by gray, sandy clay. Most of the overburden is soft, gray, silty shale. The remainder is yellow-brown, poorly cemented, fine-grained sandstone that is locally erosion resistant owing to the presence of calcareous cement, a few discontinuous beds of limestone less than 3 feet thick, and thin coalbeds. Gravel deposits, probably less than 30 feet thick, cap the highlands in the center of the area. The faults shown on figure 13 have displacements ranging from 25 to 50 feet.

Location 17: Tongue River-Pumpkin Creek Divide Deposit

The southwestern part of T 3 N, R 48 E, along the crest of the Tongue River-Pumpkin Creek divide, is underlain by the Flowers and the

TABLE 5. - Analyses for Sawyer coalbed in Pumpkin Creek deposit, as-received basis[1/]

Hole No.[2/]	PC-3	PC-9	PC-15	PC-15	PC-23	PC-29
Interval sampled . . feet. .	123 to 155.5	104.5 to 130.5	52 to 64	112 to 124	105 to 142	89 to 121.5
Proximate analysis, percent:						
Moisture	31.13	32.21	30.88	30.97	30.15	30.99
Volatile matter	28.48	28.01	28.69	27.44	28.29	28.40
Fixed carbon	33.58	32.64	33.89	31.60	33.11	33.97
Ash	6.81	7.14	6.54	9.99	8.45	6.64
Ultimate analysis, percent:						
Hydrogen	6.51	6.58	6.43	6.39	6.37	6.49
Carbon	44.78	44.14	45.27	42.71	45.18	45.51
Nitrogen	.74	.74	.82	.76	.77	.74
Oxygen	40.86	40.98	40.63	39.80	38.78	40.38
Sulfur	.30	.42	.31	.35	.45	.24
Chlorine	.00	.00	.00	.00	.00	.00
Heating value . . Btu/lb. .	7,490	7,370	7,510	7,140	7,550	7,570
True specific gravity	1.54	1.55	1.56	1.60	1.55	1.55
Ash fusibility, °F:[3/]						
IT	2,250	2,190	2,210	2,080	2,080	2,140
ST	2,300	2,240	2,260	2,140	2,120	2,190
FT	2,350	2,320	2,310	2,190	2,160	2,270

1/ Data from Grand Forks Coal Research Laboratory.
2/ Refers to drillhole numbers on figure 13.
3/ IT, initial deformation temperature; ST, softening temperature; FT, fluid temperature; oxidizing atmosphere. American Society for Testing and Materials. Tentative Method of Test for Fusibility of Coal and Coke Ash. D1857-66T in 1967 Book of ASTM Standards; Part 19, Gaseous Fuels; Coal and Coke. Philadelphia, Pa., 1967, pp. 356-361.

Terret coalbeds (fig. 14). As near as can be determined from the limited topographic data, cover over the Flowers bed should not exceed 120 feet.

The stratigraphic interval between the Flowers bed and the underlying Terret bed is 80 feet in the southwestern part of the area, decreasing to 50 feet in the northwestern part and 35 feet in the eastern part. The strippable reserve indicated here is predicated on simultaneous stripping and mining of the Flowers and Terret beds. Overburden is shale, sandstone, and clinker.

On the basis stated, the estimated total strippable reserve in the Flowers coalbed is 15.3 million tons. The average thickness is estimated to be 7.6 feet. The total strippable reserve of the Terret bed is 45.5 million tons; average coal thickness is estimated to be 7.9 feet. Quality of the coal in this deposit would be within the range of composition for the Flowers and Terret coals given in table 4.

Colstrip-Brandenburg Area (10, 14, 15)

Location and Geographic Features

The Colstrip-Brandenburg area covers about 900 square miles in southern Rosebud County, Mont. It is bounded on the north by the north line of T 4 N, on the east by Custer and Powder River Counties, on the south by the south line of T 1 S, and on the west by Treasure and Big Horn Counties.

Altitudes within the field range from about 2,800 to 4,457 feet, a difference of some 1,660 feet. Local relief seldom exceeds 300 feet.

The Yellowstone River flood plain north of the Colstrip-Brandenburg area is as much as 2 miles wide. The flood plain is bordered by a succession of gravel-covered benches, which, within 4 to 8 miles of the south side of the river, rise by steps to uplands that have a subdued, rolling, and barren appearance where the surface strata are soft clay and shale. Farther south, younger, more resistant beds of sandstone and clinker crop out. Such harder layers form the tops of ridges in the more dissected southwestern part of the area and extend northerly as the divides between Rosebud Creek and Tongue River on the east, Rosebud Creek and Armells Creek in the central part of the area, and Armells Creek and Sarpy Creek on the west.

Forsyth (population 1879), the county seat and the only incorporated town, is on the Yellowstone River north of the area. Colstrip, an unincorporated town of about 75, serves as the residential area for the Colstrip mine.

U.S. Highway 10-12-312 and Interstate Highway 94 pass east-west through Forsyth. U.S. Highway 212 passes east-west through Lame Deer, just south of the area. State Highway 315 passes north-south through Colstrip. The remainder of the area is accessible via graded county roads.

More than 90 percent of the land area in central Rosebud County is used for raising of livestock. Less than 5 percent of the land is under cultivation, chiefly for small grains. About two-thirds of the crops are grown by dry-farming methods; irrigation is generally restricted to the flat valley bottoms where water is available.

The main lines of the Northern Pacific and the Milwaukee Road pass east-west along the Yellowstone River through Forsyth. A spur line of the Northern Pacific extends from Forsyth to Colstrip.

Coalfield Geology

All coalbeds of importance in the Colstrip-Brandenburg area are found in the Tongue River Member. Maximum thickness of the Tongue River Member within the area is 1,686 feet. It is composed of sandstone and shale interbedded with sandy shale, carbonaceous shale, coalbeds, and a few thin, fresh-water, limestone beds.

In general, the Tongue River Member gradually thickens in a southwesterly direction across the coalfield. Thus, the stratigraphic interval between beds is expected to increase in this direction.

Strata within the coalfield are nearly flatlying. Dip seldom exceeds 1°. Maximum dip of the beds is about 3° southeastward from Porcupine dome in the northern part of the area. The rocks are slightly disturbed at a few places, but no faults are known in the areas suggested for stripping.

Mining Considerations

Mining conditions would vary considerably across the coalfield. In some areas the clinker would necessitate blasting. Thick sandstone beds, ferruginous concretion beds that are abundant in at least four horizons, and particularly fresh-water limestone beds would all need preliminary blasting.

Blasthole drilling would be hampered by the presence of terrace gravels. In the Greenleaf Creek-Miller Creek area, terrace gravels that contain pebbles, cobbles, and angular clinker blocks as much as 4 feet in diameter, cover extensive portions of the proposed strip area. Such alluvial deposits are as much as 25 feet thick. In part of the area, the lower 3.5 feet of alluvium has been cemented by limy material into a loose conglomerate.

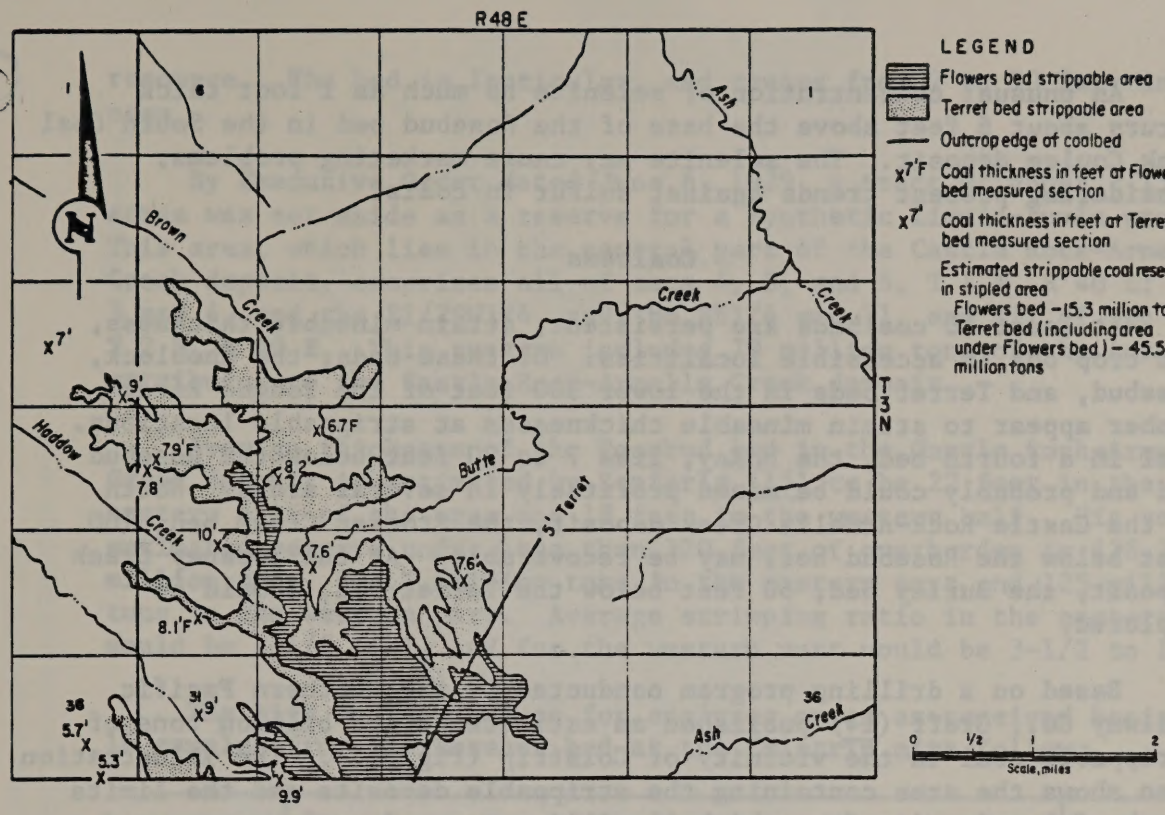

FIGURE 14. – Tongue River–Pumpkin Creek Divide Deposit, Ashland–Coalwood Area. (Based on plate 11, U.S. Geol. Survey Bull. 847)

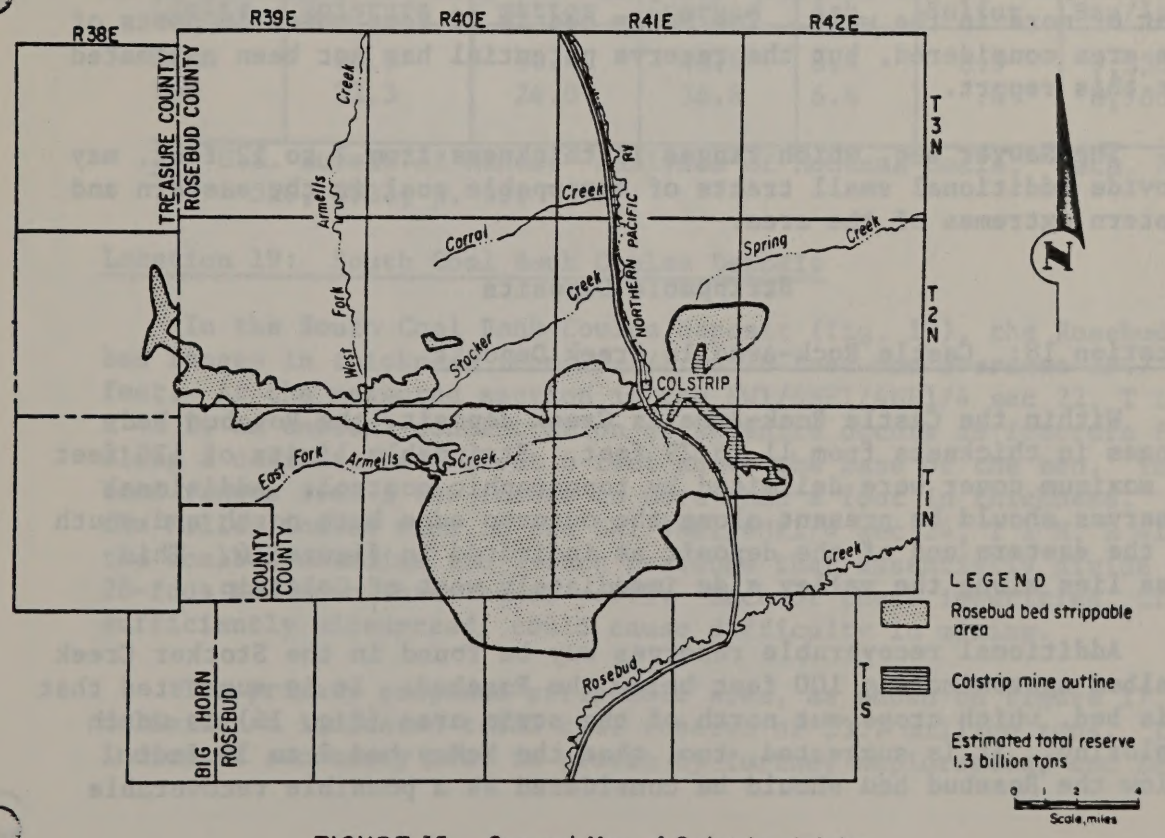

FIGURE 15. – General Map of Colstrip vicinity. (Based on plate 1, reference 14)

An unusual concentration of selenite as much as 1 foot thick occurs about 6 feet above the base of the Rosebud bed in the South Coal Bank Coulee deposit. The selenite may cause marketing problems, considering present trends against sulfur in coals.

Coalbeds

At least 10 coalbeds are persistent, attain mineable thickness, and crop out in accessible localities. Of these beds, the Knoblock, Rosebud, and Terret beds in the lower 500 feet of the Tongue River Member appear to attain mineable thicknesses at strippable locations. Coal in a fourth bed, the McKay, lies 7 to 30 feet below the Rosebud bed and probably could be mined profitably in several areas. North of the Castle Rock-Armells Creek deposit, the Stocker Creek bed, 100 feet below the Rosebud bed, may be recoverable. At the Sweeney Creek deposit, the Burley bed, 60 feet below the Terret bed, should be explored.

Based on a drilling program conducted by the Northern Pacific Railway Co., Groff (14) published an estimate of 1.3 billion tons of strippable coal in the vicinity of Colstrip (fig. 15). The illustration also shows the area containing the strippable deposits and the limits of the Colstrip mine from which 44 million tons of coal was removed.

The McKay bed is about 7 feet below the Rosebud bed in the eastern part of the Colstrip area, and the interval increases to 30 feet or more in the west. The McKay bed is 10 feet thick in parts of the area considered, but the reserve potential has not been estimated for this report.

The Sawyer bed, which ranges in thickness from 2 to 12 feet, may provide additional small tracts of strippable coal in the eastern and western extremes of the area.

Strippable Deposits

Location 18: Castle Rock-Armells Creek Deposit

Within the Castle Rock-Armells Creek deposit, the Rosebud bed ranges in thickness from 11 to 29 feet. Strippable limits of 120 feet of maximum cover were delimited by topographic control. Additional reserves should be present along the outcrop edge both north and south of the eastern end of the deposit as indicated in figure 16. This area lies along the valley side immediately west of Colstrip.

Additional recoverable reserves may be found in the Stocker Creek coalbed approximately 100 feet below the Rosebud. It is suggested that this bed, which crops out north of the strip area (fig. 16) is worth exploring. It is suggested, too, that the McKay bed 7 to 30 feet below the Rosebud bed should be considered as a possible recoverable

resource. The bed is lenticular, and ranges from 2 to 10 feet in thickness.

By Executive Order dated June 6, 1929, a tract of about 2,150 acres was set aside as a reserve for a synthetic liquid-fuels program. This area, which lies in the central part of the Castle Rock-Armells Creek deposit, comprises all of secs 4, 5, and 6, T 1 N, R 40 E; lots 3 and 4, and the E1/2SW1/4, and the SE1/4 sec 31, and all of sec 32, T 2 N, R 40 E. This reserve includes 70 million tons of the total attributed to the Castle Rock-Armells Creek deposit.

Average thickness of the Rosebud bed in the Castle Rock-Armells Creek deposit is estimated by Kepferle (15) to be 22 feet in the eastern half of the area and 18 feet in the western half. His total estimated reserve under less than 120 feet of overburden is 428.3 million tons, 303.3 million tons in the eastern part and 125 million tons in the western part. Average stripping ratio in the eastern part would be 2-1/2 to 1, and for the western part would be 3-1/2 to 1.

The high and low values for analyses on an as-received basis of 16 samples from the Rosebud bed at the Colstrip mine follow:

	Composition, percent[1/]					
Limits	Moisture	Volatile matter	Fixed carbon	Ash	Sulfur	Heating value, Btu/lb
High	26.5	30.4	40.6	8.4	0.9	9,330
Low	22.3	26.0	38.8	6.4	.4	8,780

1/ U.S. Bureau of Mines. Analyses of Montana Coals. Tech. Paper 529, 1932, p. 59.

Location 19: South Coal Bank Coulee Deposit

In the South Coal Bank Coulee deposit (fig. 17), the Rosebud bed ranges in thickness from 23-1/2 to 28 feet and averages 25.7 feet. At the measured section in the NW1/4NE1/4NE1/4 sec 22, T 1 N, R 41 E, an unusual concentration of selenite occurs as fracture filling along a definite band about 6 feet above the base of the bed. The band ranges from a few inches to more than a foot in thickness. At the Miller Coulee mine in the NW1/4NW1/4NE1/4 sec 24, T 1 N, R 41 E, the coalbed contains two 2-inch partings that essentially divide the 28-foot bed into three equal parts. Each of these impurities, if sufficiently widespread, could cause difficulty in mining.

The primary proposed strippable area, as shown on figure 17, delimits an indicated total coal reserve of 23.7 million tons. If the indicated secondary area is proven by further exploration, and if the

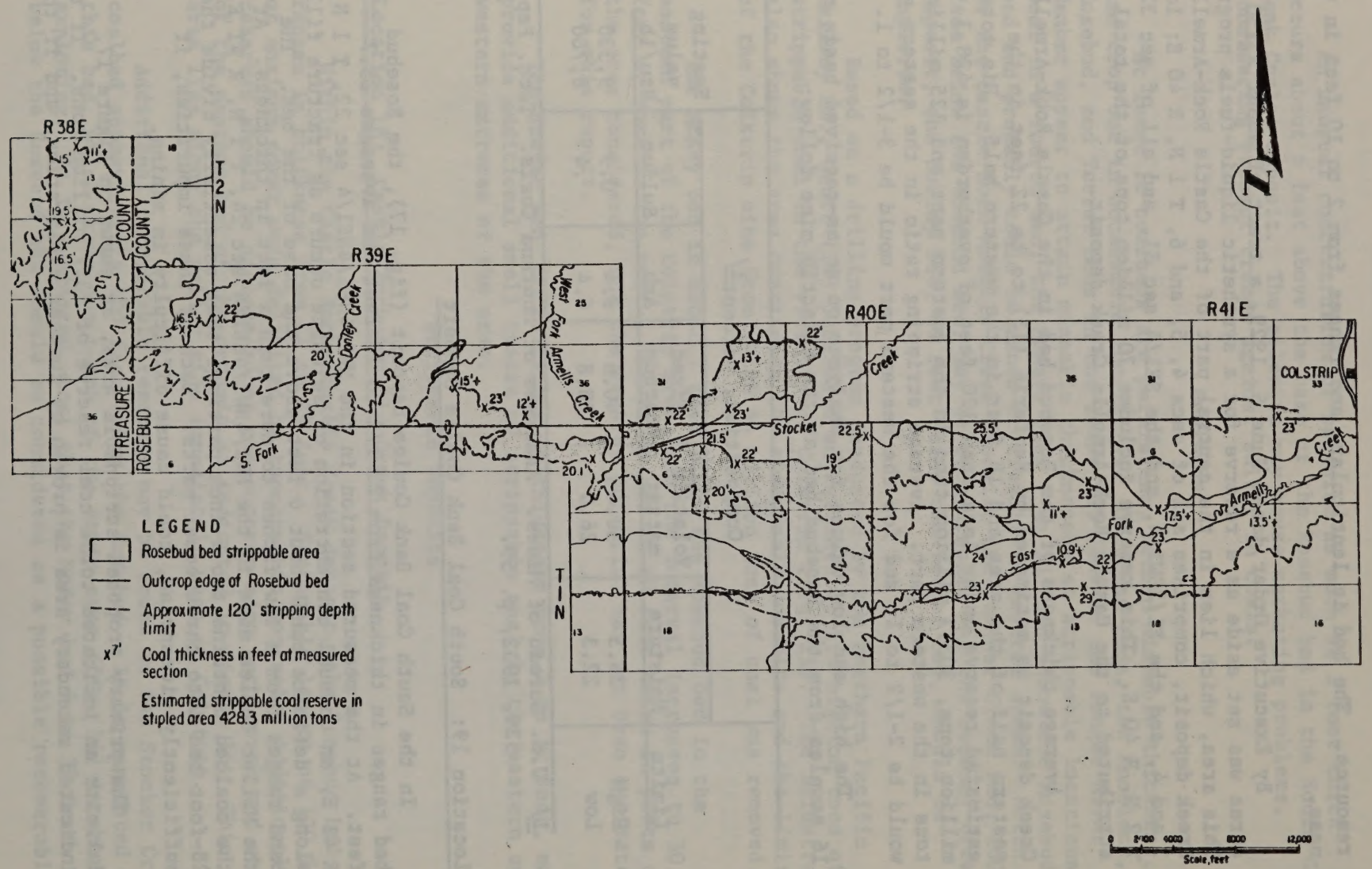

FIGURE 16. – Castle Rock–Armells Creek Deposit, Colstrip–Brandenburg Area.
(Based on plates 51 and 53, U.S. Geol. Survey Bull. 995)

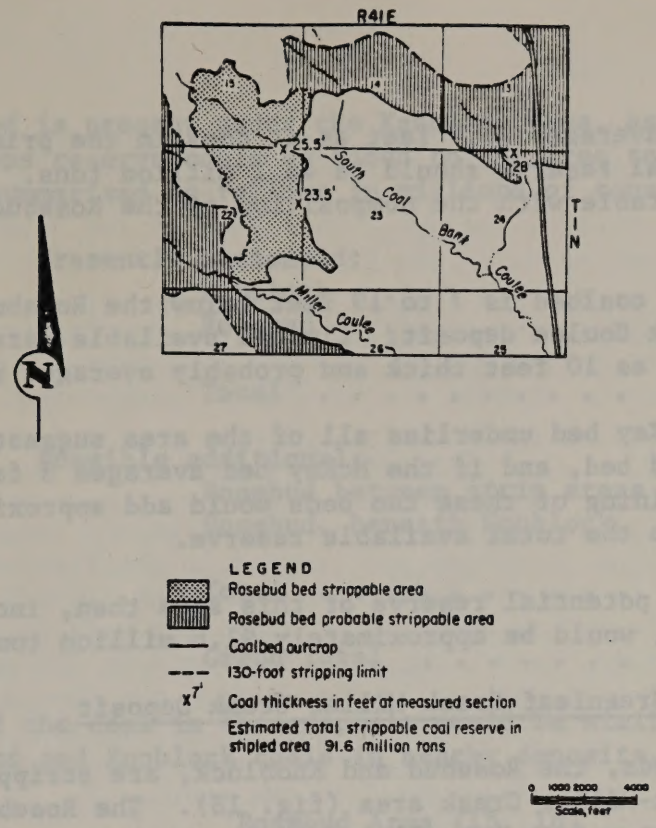

FIGURE 17. – South Bank Coulee Deposit, Colstrip–Brandenburg Area. (Based on figure 60, U.S. Geol. Survey Bull. 995)

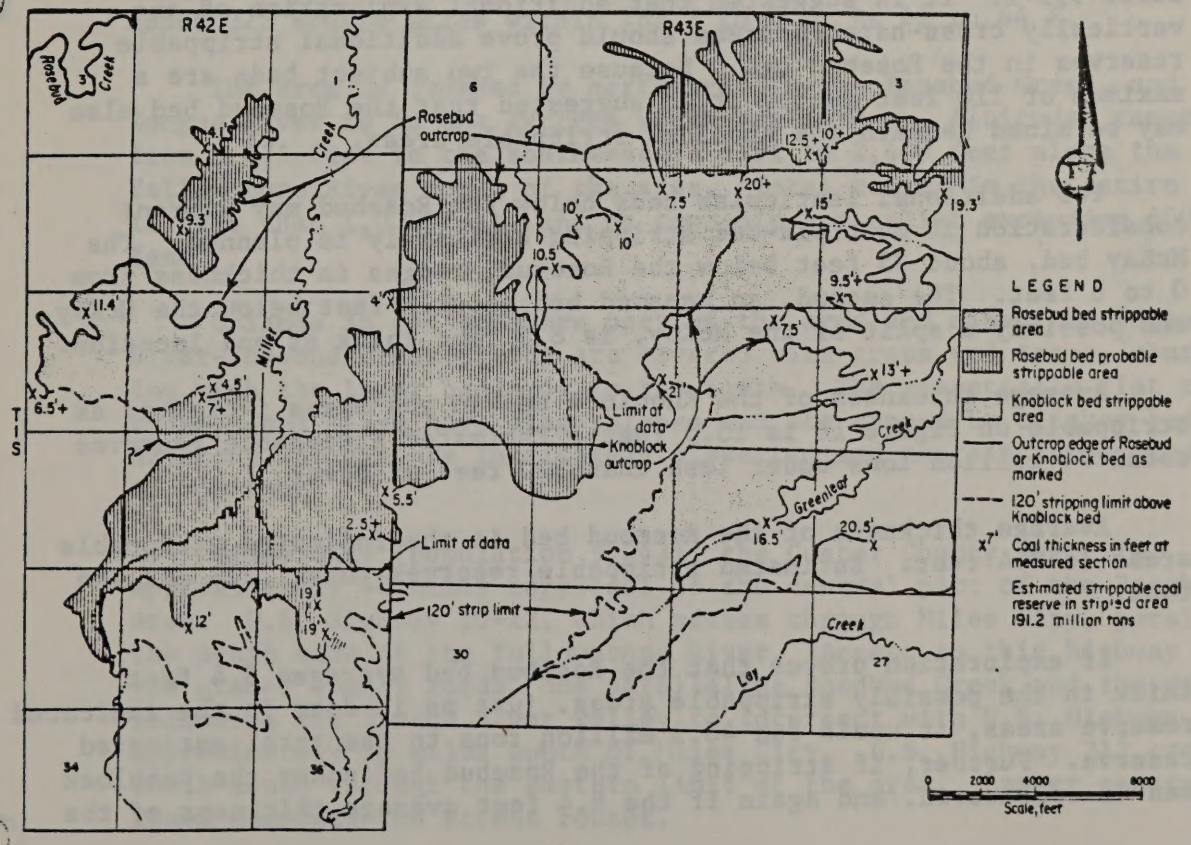

FIGURE 18. – Greenleaf Creek–Miller Creek Deposit, Colstrip–Brandenburg Area. (Based on plates 49 and 50 U.S. Geol. Survey Bull. 995)

bed thickness averages 25.7 feet as it does in the primary area, the additional total reserve should be 46.2 million tons. Coal quality would be comparable with the composition of the Rosebud bed at the Colstrip mine.

The McKay coalbed is 7 to 10 feet below the Rosebud bed at the South Coal Bank Coulee deposit. Limited available data indicate this bed is as much as 10 feet thick and probably averages about 8 feet.

If the McKay bed underlies all of the area suggested as strippable for the Rosebud bed, and if the McKay bed averages 8 feet thick, simultaneous mining of these two beds would add approximately 21.7 million tons to the total available reserve.

The total potential reserve of this area then, including the three listed sources, would be approximately 91.6 million tons.

Location 20: Greenleaf Creek-Miller Creek Deposit

Two coalbeds, the Rosebud and Knoblock, are strippable in the Greenleaf Creek-Miller Creek area (fig. 18). The Rosebud, the lower of the two, ranges from 4 to 11.4 feet in thickness. Measured sections of the Knoblock, 90 to 110 feet higher in the stratigraphic section, range from 2.5 to 21 feet in thickness. Strippable areas indicated on figure 18 have been taken from Plates 49 and 50 of U.S. Geol. Survey Bull. 995-I. It is suggested that additional exploration of the vertically cross-hatched areas should prove additional strippable reserves in the Rosebud bed. Because the two subject beds are a maximum of 110 feet apart, it is suggested that the Rosebud bed also may be mined beneath the Knoblock strippable areas.

Two additional lenticular beds below the Rosebud may warrant consideration if multiple-bed stripping ultimately is planned. The McKay bed, about 35 feet below the Rosebud, ranges in thickness from 0 to 6 feet. The second, an unnamed bed about 8 feet below the McKay, and possibly a split of the McKay, is 8.5 feet thick at one location.

Average thickness of the Knoblock bed in the areas indicated as strippable on figure 18 is 13.5 feet. Estimated strippable reserves total 74 million tons under less than 120 feet of cover.

Average thickness of the Rosebud bed in the indicated strippable areas is 8.4 feet. Estimated strippable reserves total 22.8 million tons.

If exploration proves that the Rosebud bed averages 8.4 feet thick in the possibly strippable areas, just as it does in the indicated reserve areas, it would add 48.3 million tons to the total estimated reserve. Further, if stripping of the Rosebud bed under the Knoblock bed is considered, and again if the 8.4 feet average thickness of the

Rosebud bed is present under the Knoblock area, an additional 46.1 million tons reserve could be added to the area total. Reserves then could be summarized as follows in millions of tons:

Presently indicated:	
Knoblock	74.0
Rosebud	22.8
Total	96.8
Possible additional:	
Rosebud between strip areas	48.3
Rosebud, beneath Knoblock	46.1
Total	94.4
Grand Total	191.2

Quality of the coal in this deposit would be similar to analyses given for Rosebud and Knoblock coals in nearby deposits.

Rosebud Area (15, 18)

Location and Geographic Features

The Rosebud area, Rosebud County, Mont., includes an area of about 325 square miles within Tps 2 to 4 N, Rs 42 to 44 E.

The area is crossed by northward-flowing Rosebud Creek, and the Tongue River is in the extreme southeast corner. Altitudes range from 3,475 feet in the southwestern part to 2,400 feet along the Yellowstone River north of the area. Total relief in the entire area is less than 1,000 feet, and no township has relief exceeding 600 feet.

Uplands in the southern part of the area and along the Tongue River-Rosebud Creek divide are covered with grass and trees, contrasting with the lower badlands to the north. The essentially flat topped uplands and mesas have steep slopes and are capped by clinker beds. Adjacent valleys are intricately dissected and contain large areas of badlands.

Miles City (population 9,243), the Custer County seat, is approximately 40 miles northeast of the central part of the Rosebud area. U.S. Highway 10-12, which passes through Miles City, parallels the south side of the Yellowstone River. Access to this highway is via graded county roads, one paralleling Rosebud Creek and the other following the Tongue River valley to intersect with U.S. Highway 212 approximately 12 miles south of Miles City. U.S. Highway 212 crosses north-south through the eastern limit of the area. Lesser county roads complete the access routes.

The nearest railhead is at Colstrip approximately 20 miles west of the southern part of the area. Colstrip is the end of a spur branch of the Northern Pacific Railway. Mainlines of the Northern Pacific and the Milwaukee Road parallel the Yellowstone River north of the area.

Farming, principally alfalfa and grain, is confined to the river valleys. Cattle grazing is the principal industry. Some lumber is produced from timber growing on the high clinker-capped hills.

Coalfield Geology

The Upper Cretaceous Hell Creek Formation and the overlying Tertiary Fort Union Formation are exposed in the Rosebud area. In central Rosebud County the Fort Union Formation attains a thickness of about 2,175 feet, and is composed of the lower unit or Tullock Member, the middle unit or Lebo Member, and the upper unit or Tongue River Member. Because the beds are essentially flat-lying, and because the topographic rise is generally from north to south, the oldest beds are exposed along the northern part of the area, and progressively younger beds are exposed as the land surface rises to the south.

Two or three local coalbeds of negligible importance are found in the upper 100 feet of the Tullock Member. Likewise, the coalbeds interbedded with shale in the Lebo Member are not economically interesting.

The coalbeds of economic potential are found in the Tongue River Member, which is exposed in the high southern part of the Rosebud area. Exposures cover approximately one-third of the area. The Tongue River Member is composed of beds of sandstone, sandy shale, carbonaceous shale, and coal. Although the member is estimated originally to have been 1,626 to 1,780 feet thick, the upper part has been removed by erosion, leaving a present maximum of about 400 feet.

Predominant structural features of the area are the Tongue River syncline, whose axis follows the Tongue River valley, trending northeastward from T 3 N, R 46 E, to T 5 N, R 47 E, and the anticlinal nose that plunges southeastward from T 5 N, R 42 E, toward the Tongue River. Both limbs of the Tongue River syncline rise gradually with numerous irregularities and undulations. Maximum structural relief in this area is 250 feet. Strata usually dip less than 1°, although a few local dips of 3° are reported near the few small normal faults.

Mining Considerations

The low average dip of strata in the area would permit easy mine development with large equipment. Rocks in the stratigraphic section are comparatively soft, except in zones where clinkers are present. The coal is usually found on the upper parts of steep-sided hills and

mesas, and mine operators would have to anticipate downhill haulage over abrupt slopes from the mines to the valley floors.

Coalbeds

Eight coalbeds are recognized in the Tongue River Member within the Rosebud area. Of these eight, three are thick and extensive enough to be of potential economic importance.

The Burley bed, stratigraphically the lowest, crops out in the Rosebud area west of the Tongue River. West of Rosebud Creek the bed is 5 to 8.5 feet thick, but northward along the Tongue River-Rosebud Creek divide, it thins from 6 feet 2 inches in the southern part of T 2 N, R 43 E, to 3 feet in the northeastern part of the same township.

In the extreme southern part of T 4 N, R 45 E, a bed at the same horizon as the Burley, and considered to be the Burley, begins to thicken rapidly toward the north. It reaches a maximum measured thickness of 9.5 feet in sec 12, T 4 N, R 44 E. North of this locality, it has burned along the outcrop. Where present, the Burley coal is clean and of good quality.

The Terret bed has burned along most of its outcrop. This bed ranges from 1.8 feet to 17 feet in thickness on the Rosebud Creek-Tongue River divide. A mile north of T 3 N, R 44, it splits into thin coalbeds. Also, along the west side of Rosebud Creek the Terret bed splits and thins to less than 18 inches of coal.

Strippable deposits

Location 21: Rosebud Creek-Tongue River Divide Deposit

The Terret coalbed underlies the Rosebud Creek-Tongue River divide in Tps 2 and 3 N, Rs 43 and 44 E (fig. 19). The outcrop edge is almost continuously burned. It is estimated, however, that coal averaging 9.8 feet thick underlies 18.5 square miles of the divide area. The estimated total reserve is 209.9 million tons.

Pierce stated (18) that in T 3 N, R 44 E, "unburned coal underlies narrow strips along the main divide and the minor divides. The cover is between 100 and 150 feet." And in referring to T 2 N, R 44 E, he said "The cover over the Terret bed on the divide is generally between 100 and 200 feet." It is also stated that "A local bed 18 inches or less in thickness occurs 135 feet above the Terret in secs 7, 18, and 19." Within T 2 N, R 44 E, that area underlain by the local bed over the Terret bed has been excluded from the strippable reserve area; thus, the maximum stripping depth in this township should not exceed 135 feet.

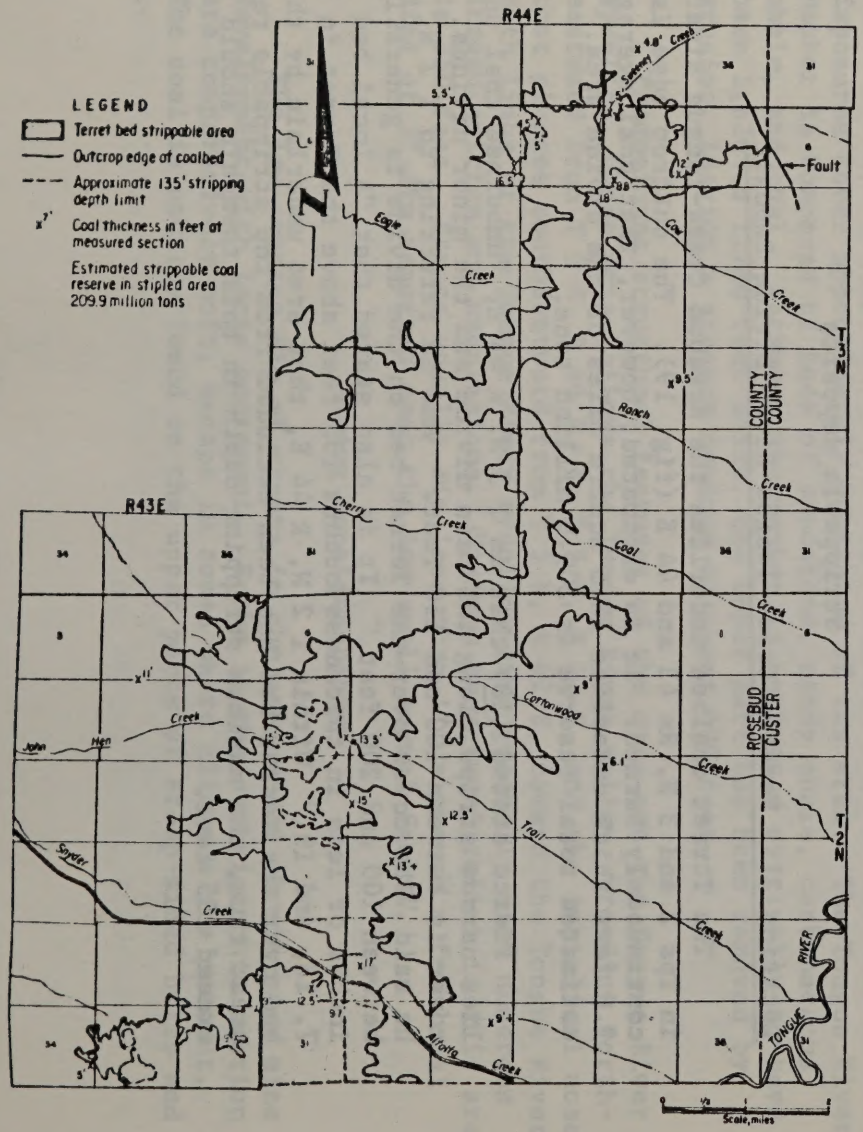

FIGURE 19. – Rosebud Creek–Tongue River Divide Deposit, Rosebud Area.
(Based on plate 11, U.S. Geol. Survey Bull. 847)

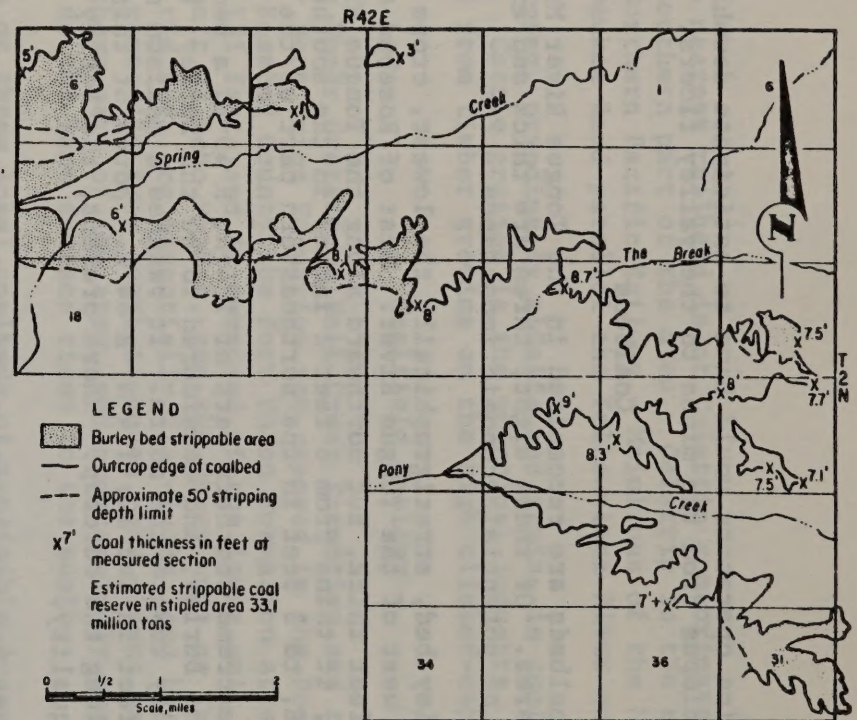

FIGURE 20. – Burley Deposits, Rosebud Area.
(Based on plate 11, U.S. Geol. Survey Bull. 847)

Along Sweeney Creek, measured sections indicate the outcrop thickness ranges from 1.8 to 16.5 feet. At the northern end of the deposit, the average thickness of the Terret bed is 7.6 feet. Near the northeast corner of sec 10, T 3 N, R 44 E, the bed consists of a series of alternating thin bands of coal and shale, making an uneconomic sequence. Elsewhere, the sections indicate reasonably clean subbituminous coal.

The Terret bed is overlain by gray to yellowish-brown silty and sandy shale and very fine-grained friable sandstone. There are at least two dense fresh-water limestone beds and one thin coalbed within 120 feet of the top of the Terret coal. Ferruginous concretions are abundant in at least four separate horizons.

South of Snyder and Alfalfa Creeks, the Terret coalbed ranges in thickness from 9 to 17 feet. Average thickness is 11.2 feet. One thin split is known in the western part of the area; aside from this, the coal is consistently of good quality.

Location 22: Burley Deposits

Strippable deposits along the outcrop of the Burley coalbed in T 2 N, Rs 42 and 43 E, are indicated on figure 20. The area shown and the stripping limit of 50 feet of cover are the same as those used by Pierce (18). Data are too incomplete to establish an approximate location for a stripping limit having 120 feet of overburden. Additional reserves should be available, not only by mining along the outcrop between the strippable areas shown, but by increasing the arbitrary 50-foot stripping limit.

The strippable reserve in three areas indicated on figure 20 totals 33.1 million tons of subbituminous coal. Average coal thickness is estimated to be 7 feet.

Pine Hills Area (4)

Location and Geographic Features

The Pine Hills area centers in sec 13, T 7 N, R 49 E, Custer County, Mont., approximately 14 miles east of Miles City. The Pine Hills are remnants of the Tongue River Member isolated by erosion by the Yellowstone River on the northwest, Powder River on the east, Mizpah Creek on the southeast, Pumpkin Creek on the southwest, and the Tongue River on the west.

Altitudes within the Pine Hills range from approximately 2,270 to 3,330 feet, but within the coal-bearing region average about 3,150 feet. Both the high elevations and the coal are in the central part of the described area.

In general, steep slopes and some badland topography have formed near the main drainages. In the vicinity of the strippable deposit,

the south side of the ridge is steep and intensively gullied, but on the north side the land falls away gently, and the slope is modified in places by low, rounded, hills usually less than 60 feet high. Unfavorable topography bounds the deposit in two places. In sec 24, T 7 N, R 49 E, and in sec 18, T 7 N, R 50 E, high steep slopes probably make the deposit too narrow for economic stripping. A narrow finger of unburned coal that extends southeastward across secs 4, 9, and 10, T 7 N, R 49 E, was excluded from the stripping area because it is too narrow, is not connected with the main deposit and underlies an intensely dissected ridge.

Most of the land overlying the deposit is grassy and is used for cattle grazing. Some of the smooth slopes in secs 11, 14, and 15, T 7 N, R 49 E, on the north side of the ridge, are under cultivation. Pine forests border the area and extend up deep gullies on the south side of the ridge.

Miles City is 14 miles west via U.S. Highway 12, which crosses the north edge of the proposed strip area. Several county roads in the immediate vicinity could provide additional access for a mine. The main lines of the Northern Pacific Railway and the Milwaukee Road pass through Miles City. The suggested strip area is approximately 800 feet higher than this railhead.

Coalfield Geology

All rocks exposed in the Pine Hills area belong to the Fort Union Formation. The basal Tullock Member, consisting of about 250 feet of dark- and light-gray shale, sandy shale, sandstone, and some thin, dirty coalbeds, is exposed along the valley of the Yellowstone River near Miles City and in the lower valleys of the Tongue River and Pumpkin Creek.

The overlying Lebo Shale Member is about 160 feet thick. The member consists predominantly of soft clay shale that weathers dull yellow or dark gray. It contains thin coalbeds of negligible value.

The Tongue River Member, the top unit of the Fort Union Formation in the Pine Hills area, is present at high elevations. Only the basal part, about 400 feet, of the Tongue River Member has survived erosion. The member is composed of sandstone, shale, sandy shale, thick coalbeds, clinker, and a few thin limestone beds. Rugged land forms of marked relief characterize most of the outcrop area. Strata in the Pine Hills area are essentially flat-lying.

Mining Considerations

Flat-lying beds in the Pine Hills area appear to be ideally suited to mining by large-scale stripping equipment. During preliminary

exploration, however, studies should be made of any hard zones encountered, particularly limestone, to be certain that the equipment selected is large enough to handle such material in the overburden without blasting.

Coalbeds

Coalbeds in the Tullock and Lebo Shale Members are too thin and dirty to be of economic interest. The E bed, also known as the Dominy Lignite Group, in the Tongue River Member, attains a thickness, lateral extent, and quality that permits its consideration for strip mining.

Strippable Deposit

Location 23: E Deposit

The E bed underlies parts of 11 sections in T 7 N, Rs 49 and 50 E. A parting, 4 to 13 feet thick, separates the bed into two benches. The upper bench ranges from 0 to 9 feet thick and probably averages 5 feet. The lower bench is 24.5 feet thick near its western outcrop. It thins to the east. Average thickness is estimated to be 10 to 15 feet.

In the area outlined in figure 21 as being strippable, the upper coal bench averages at least 6 feet thick. Estimated total strippable coal reserve in this bench is 27.6 million tons. The lower bench, 4 to 6 feet below the upper bench, is 16 to 24 feet thick and averages 19 feet. The estimated strippable reserve in this bench is 63.3 million tons, making a total reserve of 90.9 million tons under less than 120 feet of overburden.

A Bureau of Mines analysis of coal from the E bed at the Storm King Mine in sec 4, T 7 N, R 49 E, follows (4):

Form of analysis	Composition, percent					Heating value, Btu per lb
	Moisture	Volatile matter	Fixed carbon	Ash	Sulfur	
As received . . .	31.9	27.3	36.1	4.7	0.3	7,680
Moisture free . .	-	40.0	53.1	6.9	.4	11,280
Moisture and ash free . . .	-	42.9	57.1	-	.4	12,115

Wibaux Area (16)

Location and Geologic Features

The Wibaux coalfield of Wibaux and Richland Counties in eastern Montana is about 350 miles in area. The coalfield extends into North Dakota, but that portion is not included in this report.

Wibaux, the county seat of Wibaux County, has a population of about 730 and is in the southern part of the field. U.S. Highway 10 and the main line of the northern Pacific Railway pass through the area.

The topography is characterized by low, rolling fields, broken in places by buttes capped by clinker or sandstone. The climate is semi-arid, the average annual precipitation being about 15 inches. The temperature may fall as low as 30° to 40° below zero in the winter and may exceed 100° during the summer. Agriculture is the principal industry of the area and about three-fourths of the land is used for grazing; the rest under cultivation is used principally for grain.

Coalfield Geology

Surface rock in the Wibaux County consists principally of three members of the Fort Union Formation. The Ludlow is the bottom unit and is overlain successively by the Tongue River and Sentinel Butte Members. Somber gray and brown sandstone and shale beds of the Ludlow Member contain no lignite deposits of commercial importance. Strippable coal deposits in the Wibaux area are found in the Tongue River Member, which consists of sandstones, shales, and thin limestones, together with numerous beds of lignite.

Erosion has removed the Sentinel Butte Member from the strippable sites in the Wibaux area. Exposures of the Sentinel Butte Member are limited to high elevations in northern Wibaux County.

Mining Considerations

The coalbeds and enclosing rocks in the Wibaux area have an average dip less than 1°. This feature, coupled with the smooth land surface, should aid strip mining in the area. The thin limestone beds and harder sandstone bed would require light blasting. Much of the land over the Wibaux deposit is under cultivation, and surface damages would be higher than elsewhere on the grazing lands of the Fort Union region.

Coalbeds

Two deposits in the Wibaux area have been mapped by the U.S. Geological Survey (16)--the Wibaux deposit and the Four Buttes deposit, both in bed C of the Sentinel Butte lignite field.

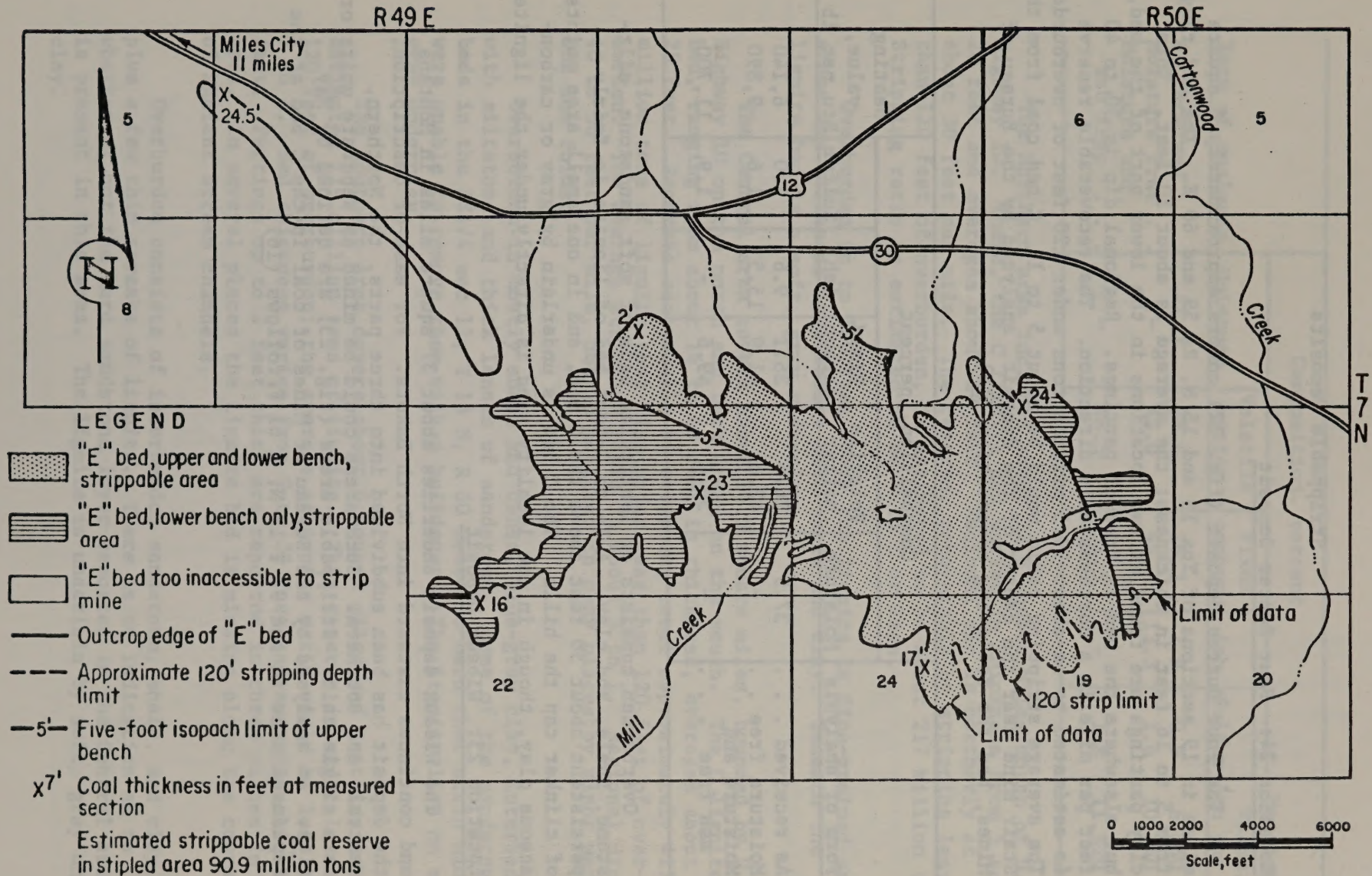

FIGURE 21. – E Deposit, Pine Hills Area.
(Based on plate 21, U.S. Geol. Survey Bull. 995)

Strippable Deposits

Location 24: Four Buttes Deposit

The Four Buttes deposit (fig. 22) covers approximately 8 square miles in 19 sections of Tps 15 and 16 N, Rs 59 and 60 E. The bed ranges from 5 to 16 feet in thickness; the average is about 10 feet. Thin clay partings are found at two locations in the lower part of the bed, but elsewhere the bed is free of partings. Regional dip is 30 to 40 feet per mile in a northeasterly direction. The recoverable reserve is estimated to be about 93.3 million tons under 120 feet of overburden. The average stripping ratio would be about 5 to 1. C bed coal from the Stair mine near the center of the deposit, analyzed by the Bureau of Mines, had the following composition (16):

Form of analysis	Composition, percent					Heating value, Btu per lb
	Moisture	Volatile matter	Fixed carbon	Ash	Sulfur	
As received . . .	37.9	26.4	26.1	9.6	1.0	6,140
Moisture free . .	-	42.6	41.9	15.5	1.6	9,890
Moisture and ash free . . .	-	50.4	49.6	-	1.9	11,700

Overburden consists of lenticular beds of soft sandstone, siltstone, shale, and clay. A 1- to 2-foot bed of lignite is fairly persistent about 50 feet above the C bed, and in one small area points of clinker cap the hills. The C bed is underlain by gray or carbonaceous clay, though in one locality sand is directly under the lignite.

Location 25: Wibaux Deposit

The Wibaux deposit underlies about 37 square miles in Montana and continues eastward into North Dakota. For ease of description, the deposit has been subdivided into three parts, the Northern, Central, and Southern. Such areas could be mined as separate units or as a single unit. Strippable areas (fig. 23) are defined by May (16). An analysis by the Bureau of Mines of coal in the C bed at the Peplinski mine in sec 9, T 12 N, R 61 F, follows (16):

Form of analysis	Composition, percent					Heating value, Btu per lb
	Moisture	Volatile matter	Fixed carbon	Ash	Sulfur	
As received . . .	41.0	24.8	26.3	7.9	0.9	6,050
Moisture free . .	-	42.0	44.7	13.3	1.6	10,240
Moisture and ash free . . .	-	48.5	51.5	-	1.8	11,820

The Northern area includes about 12.6 square miles north of U.S. Highway 10. There, the C lignite bed varies in thickness from 5 to 20 feet and averages about 14 feet. Regional dip is northerly at about 30 feet per mile. The reserve, recoverable by stripping less than 120 feet of overburden, is estimated to be about 217 million tons. Stripping ratio is estimated to be 4 to 1 or less.

Overburden up to 120 feet above the lignite is fine-grained sandstone and siltstone interbedded with shale and clay. Beneath the lignite bed is a soft, gray underclay.

The Central area covers about 14.5 square miles, bounded by U.S. Highway 10 on the north and Duck Creek on the south. The C lignite bed, ranging from about 14 to 40 feet in thickness, averages about 25 feet. Reserves recoverable by stripping total approximately 417.6 million tons of lignite that lies under less than 120 feet of overburden. The average stripping ratio is about 3 to 1. Regional dip is 40 to 50 feet per mile, but is modified in many places by minor warps and low folds.

Overburden is mostly shale and dense, blue-gray clay, interbedded with siltstone and thick lenses of sandstone. Some of the sandstone beds in the SE1/4 sec 11, T 13 N, R 60 E, are so hard that strip miners were unable to remove them with a bulldozer. The lignite lies on soft, gray underclay.

The Southern area covers about 6 square miles and contains an estimated 119 million tons of lignite. This reserve is under less than 120 feet of overburden; the average stripping ratio would be less than 3 to 1. Bed thickness varies from 9 to 22 feet and averages about 17 feet. Partings up to 2 feet thick are reported in three places in the area. In several places the lignite bed is missing along the course of ancient stream channels.

Overburden consists of interbedded sandstone, shale, and clay, plus a few thin streaks of lignite. There is no indication as to whether or not the hard sandstone layer reported in the Central area is present in this area. The lignite is underlain by soft, gray underclay.

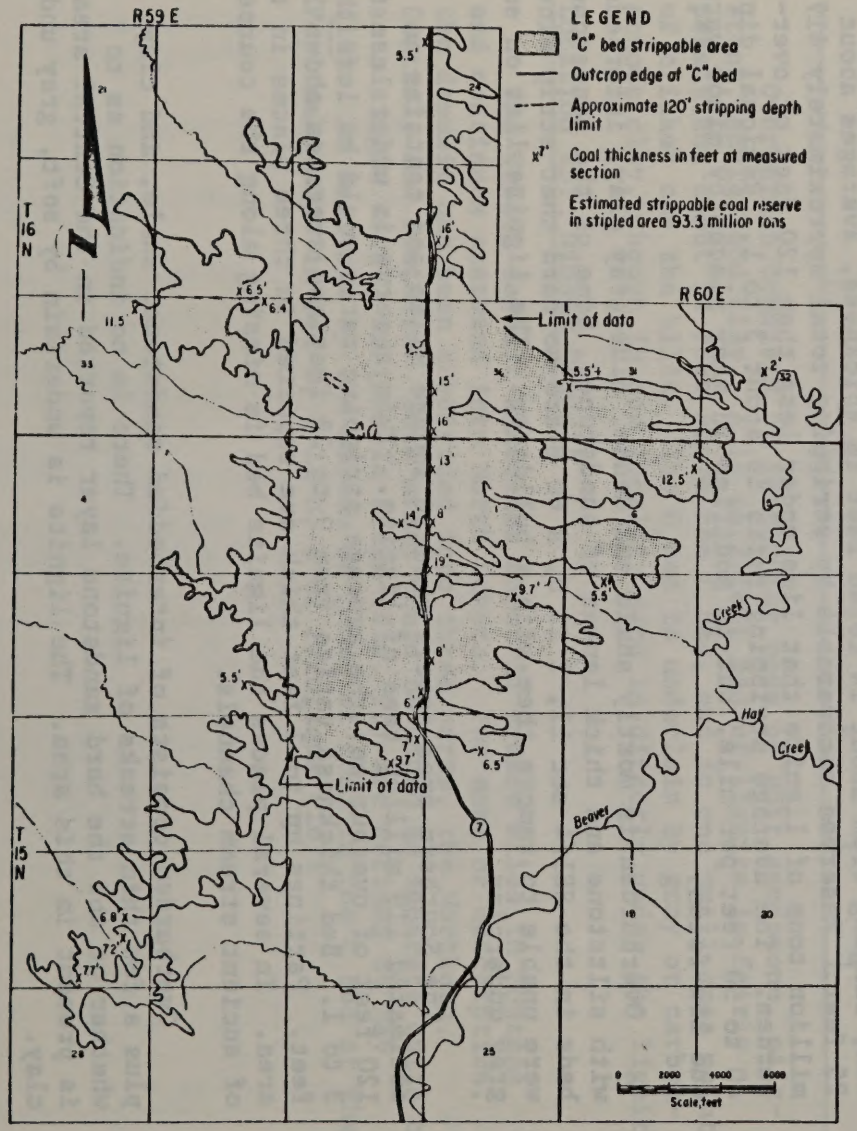

FIGURE 22. – Four Buttes Deposit, Wibaux Area.
(Based on plate 40, U.S. Geol. Survey Bull. 995)

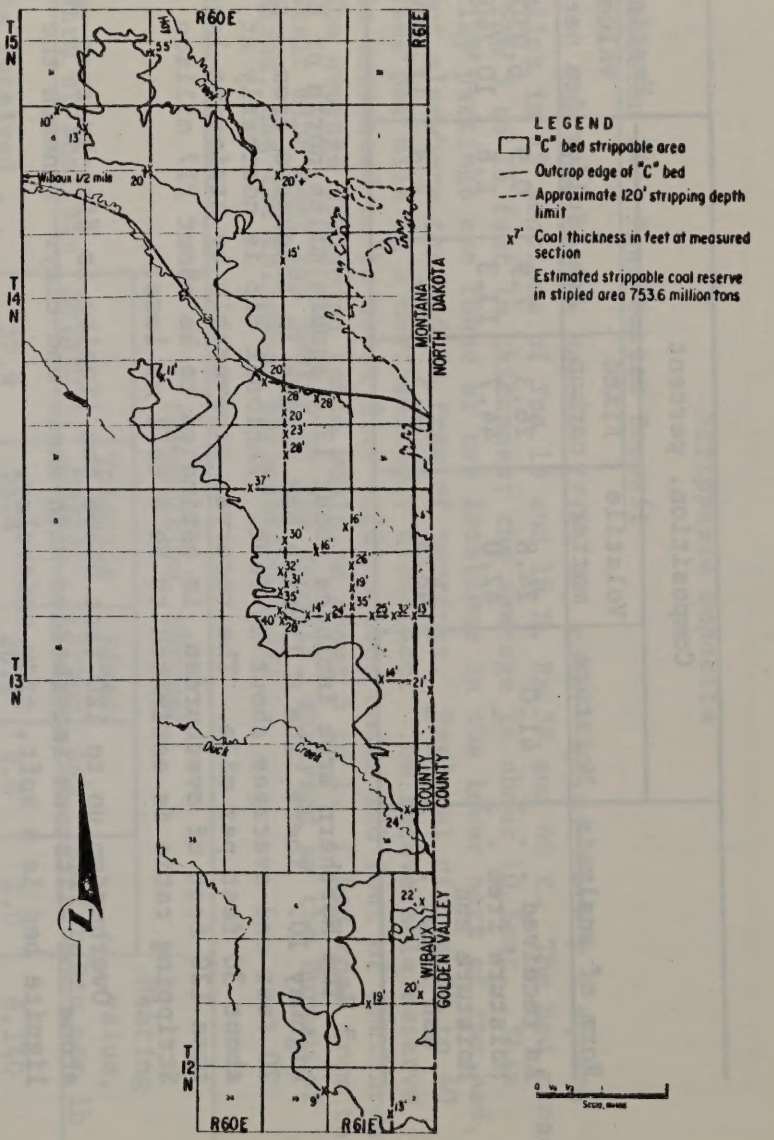

FIGURE 23. – Wibaux Deposit, Wibaux Area.
(Based on plate 39, U.S. Geol. Survey Bull. 995)

Richey-Lambert-Savage Area (7, 9, 17)

Location and Geographic Features

The Richey-Lambert-Savage area covers an area of approximately 1,188 square miles along the divide between the Yellowstone and Missouri Rivers in Richland and Dawson Counties, Mont.

Altitudes within the field range from 2,089 to 3,117 feet, a total difference of 1,028 feet. Usually within a single township, the variation is less than 350 feet. The southern part of the area is characterized by wide, trough-like valleys, or nearly featureless plains, bordered by abrupt scarps. The northwestern area is characterized by rolling hills broken by isolated buttes, small mesas, and benches.

Richey (population 595), the most important town in the area, is near the western edge of the coalfield. It is the western terminus of a branch line of the Great Northern Railway and is served by State Highway 20 and by county roads. The Great Northern, which crosses the coalfield east-west, together with spurs of other railroads, could serve as the basic parts of a coal-transport system. The existing highway and secondary roads provide an adequate transportation network between towns and possible mine locations.

Coalfield Geology

All thick coalbeds occur in the Tongue River Member. The Tongue River Member is composed predominantly of thick crossbedded or massive beds of yellow, light-buff, or white sandstone interbedded with light-gray shale and a few thin layers of brown carbonaceous shales. Discontinuous beds of calcareous concretions are common at all horizons. Many of the sandstones contain ferruginous concretions about the size and shape of toy marbles.

Structural dip is consistently about 15 feet per mile easterly. No faulting is noted.

Mining Considerations

The essentially flat-lying coalbeds permit easy strip mining. Blasting of the sandstone beds and particularly the calcareous concretion zones likely would be necessary in advance of stripping during any mining operation.

Coalbeds

Twelve coalbeds of minable thickness are known in the Richey-Lambert field. The beds vary in thickness or pinch out along the outcrop and, with the possible exception of the Carroll and Big Dirty beds,

none occur beneath every township in the field. Coalbed S, strippable in the Southern McCone County area, is a western continuation of the Carroll bed.

Numerous additional thin beds of small extent occur within the Tongue River Member. Such beds have not been mapped.

Of the 12 more important beds, only the Carroll, Lane, and Pust (pronounced Poost) beds have been investigated in sufficient detail to permit estimation of strippable reserves.

Measured sections along the outcrop of the Pust bed, in the central part of the Richey-Lambert-Savage area, range in thickness from 7 to 15.25 feet and average 10.6 feet. The bed probably underlies at least 127 square miles within Tps 21 and 22 N, Rs 52-55 E, and may extend under all or parts of the adjoining townships to the south.

Topographic mapping and vertical and horizontal control data concerning the Pust bed permit estimation of strippable limits in three areas, but it is apparent that additional study of this bed in adjacent areas is warranted.

Strippable Deposits

Location 26: Carroll Deposit

The lenticular Carroll bed ranges in thickness from 0 to 9 feet. Measured sections indicate that the Lane bed to the east and Butterfield bed to the west are probably the same because both are stratigraphically 100 feet above the Carroll bed. As delineated on figure 24, the stripping limit of the Carroll bed is assumed to be 100 feet, which coincides with the position of the Butterfield (Lane?) outcrop.

A Bureau of Mines analysis of the Carroll bed at the Carroll mine in sec 8, T 22 N, R 51 E, follows (17):

Form of analysis	Composition, percent					Heating value, Btu per lb
	Moisture	Volatile matter	Fixed carbon	Ash	Sulfur	
As received . . .	33.0	25.5	36.0	5.5	0.3	7,400
Moisture free . .	-	38.1	53.7	8.2	.5	11,050
Moisture and ash free . . .	-	41.5	58.5	-	1.6	12,030

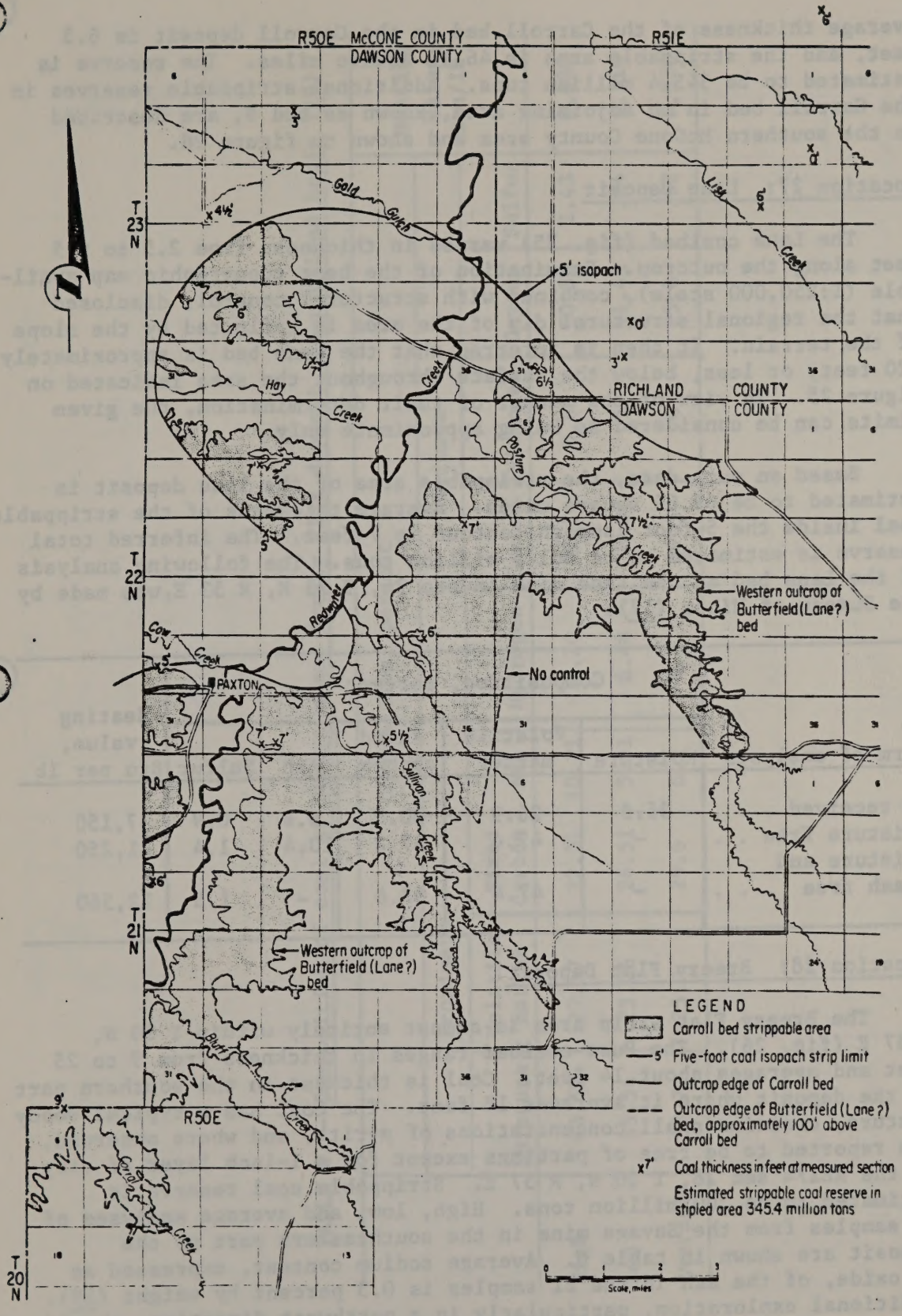

FIGURE 24. – Carroll Deposit, Richey–Lambert–Savage Area.
(Based on plate 22, U.S. Geol. Survey Bull. 847)

Average thickness of the Carroll bed in the Carroll deposit is 6.5 feet, and the strippable area is 46.13 square miles. The reserve is estimated to be 345.4 million tons. Additional strippable reserves in the Carroll bed in an adjoining area, known as bed S, are described in the southern McCone County area and shown on figure 28.

Location 27: Lane Deposit

The Lane coalbed (fig. 25) varies in thickness from 2.5 to 9.5 feet along the outcrop. Examination of the best topographic map available (1:250,000 scale), combined with structural control, disclosed that the regional structural dip of the area is reflected by the slope of the terrain. It then is inferred that the Lane bed is approximately 120 feet, or less, below the surface throughout the area indicated on figure 25. In view of the manner of their determination, the given limits can be considered as being approximate only.

Based on such data, the strippable area of the Lane deposit is estimated to be 69.66 square miles. Average thickness of the strippable coal inside the 5-foot isopach contour is 7 feet. The inferred total reserve is estimated to be 561.5 million tons. The following analysis of the Lane bed at the Lane mine in sec 26, T 23 N, R 53 E, was made by the Bureau of Mines (17):

Form of analysis	Composition, percent					Heating value, Btu per lb
	Moisture	Volatile matter	Fixed carbon	Ash	Sulfur	
As received . . .	36.5	26.9	30.0	6.6	0.9	7,150
Moisture free . .	-	42.4	47.2	10.4	1.4	11,250
Moisture and ash free . . .	-	47.4	52.6	-	1.5	12,560

Location 28: Breezy Flat Deposit

The Breezy Flat strip area is almost entirely within T 20 N, R 57 E (fig. 26). The Pust coalbed ranges in thickness from 9 to 25 feet and averages about 14 feet. Coal is thickest in the southern part of the deposit where it averages 18 feet. The coal has a typical woody texture, contains small concentrations of pyrite, and where observed, was reported to be free of partings except for a 1-inch layer of clay in the NE1/4 sec 28, T 20 N, R 57 E. Strippable coal reserve is estimated to be 200 million tons. High, low, and average analyses of 21 samples from the Savage mine in the southeastern part of the deposit are shown in table 6. Average sodium content, expressed as an oxide, of the ash in the 21 samples is 0.3 percent by weight (19). Additional exploration, particularly in a northwest direction, should prove additional strippable reserves.

TABLE 6. - Composition of coal at Savage mine, Breezy Flat deposit, as-received basis (19)

	Composition, percent									Heating value, Btu/lb
	Proximate			Ultimate						
	Moisture	Volatile matter	Fixed carbon	Ash	Hydrogen	Carbon	Nitrogen	Oxygen	Sulfur	
High	43.59	27.57	32.31	10.21	7.20	42.14	0.69	50.56	1.43	6,880
Low	35.54	23.76	26.51	5.31	6.48	36.08	.57	41.45	.24	6,310
Average	38.7	25.0	29.6	6.7	6.9	39.5	.6	45.8	.52	6,520

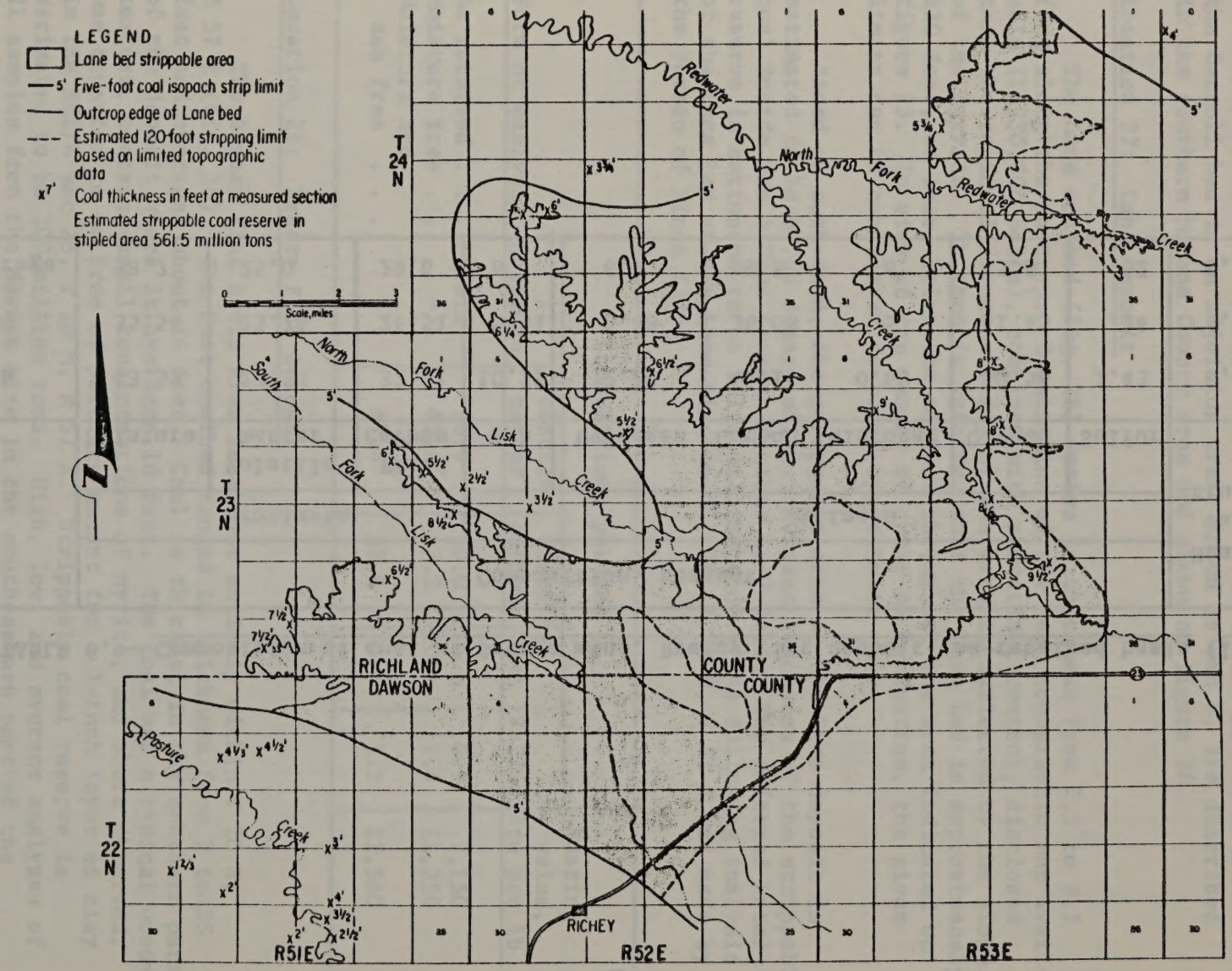

FIGURE 25. – Lane Deposit, Richey–Lambert–Savage Area.
(Based on plate 22, U.S. Geol. Survey Bull. 847)

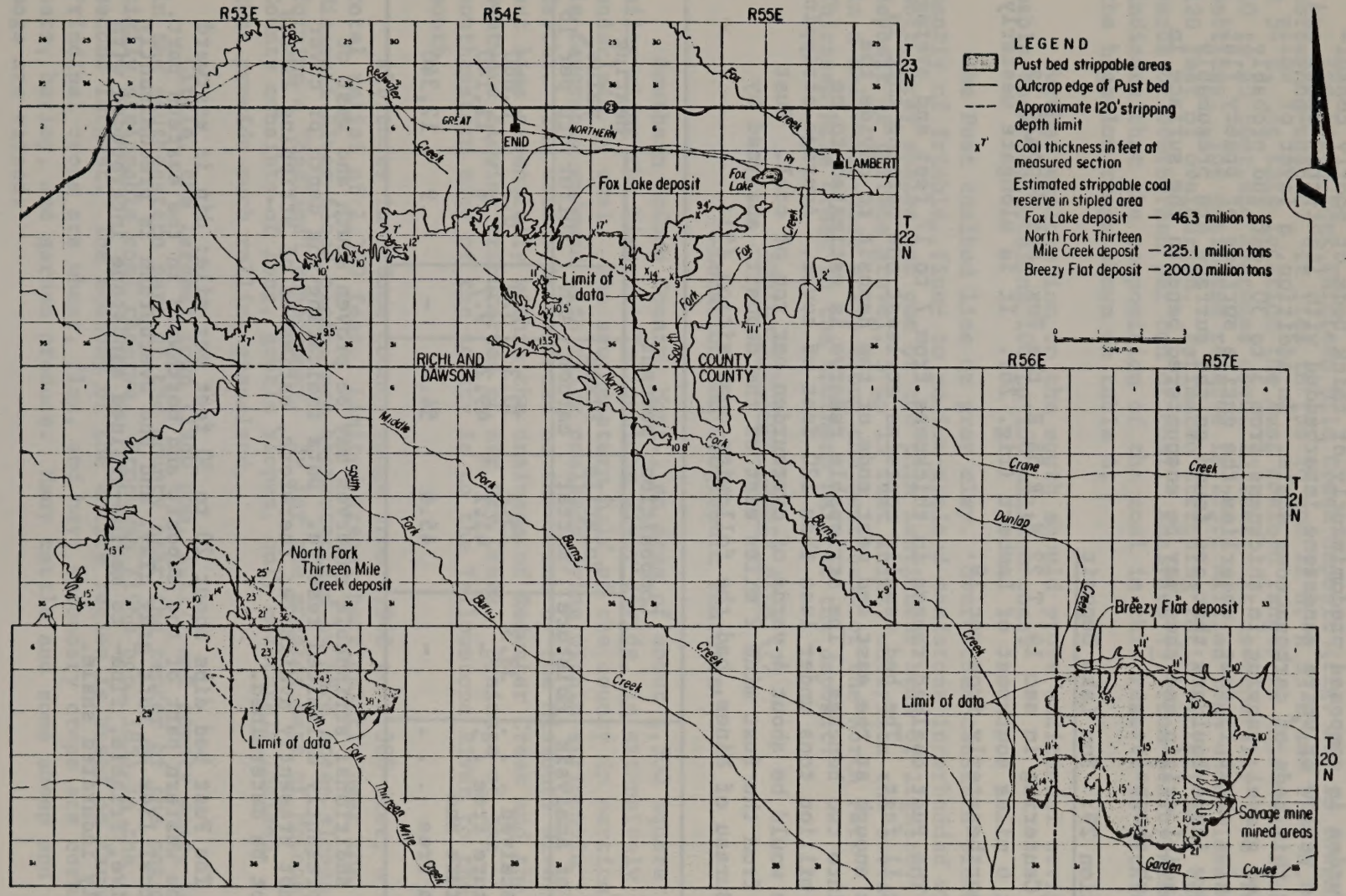

FIGURE 26. – Breezy Flat, Fox Lake, and North Fork Thirteen Mile Creek Deposits, Richey–Lambert–Savage Area. (Based on plate 22, U.S. Geol. Survey Bull. 847, and plates 46, 47, and 48, U.S. Geol. Survey Bull. 995)

Within this deposit, the Pust bed dips about 15 feet per mile to the east-northeast. The coal lies on soft gray or gray-blue clay. Overburden is composed predominantly of thick beds of poorly consolidated yellow or white sandstone interbedded with light-gray shale and a few thin beds of carbonaceous shale. In addition, a layer of well-rounded gravel, ranging in thickness from 5 to 30 feet and probably averaging about 15 feet, underlies the entire surface of Breezy Flat. The few large boulders that are found on the surface are presumably of glacial origin and thus may be encountered beneath the surface in outwash channels.

Location 29: Fox Lake Deposit

Centering in sec 19, T 22 N, R 55 E, the Fox Lake deposit is about 6 miles southwest of Lambert (fig. 26). It is elongate westerly and northeasterly from sec 19.

The Pust coalbed ranges in thickness from 7 to 17 feet and averages about 11 feet. The bed usually contains at least one parting that is thick enough at the east and west ends of the deposit to divide the bed into two benches. The strippable reserve is estimated to be 46.3 million tons under less than 120 feet of cover. Average stripping ratio would be about 4 yards of overburden per ton of coal. Pust coal from the Pust mine 2 miles east of the deposit, analyzed by the Bureau of Mines, had the following composition (9):

Form of analysis	Composition, percent					Heating value, Btu per lb
	Moisture	Volatile matter	Fixed carbon	Ash	Sulfur	
As received . . .	38.3	25.4	30.3	6.0	0.5	6,880
Moisture free . .	-	41.1	49.2	9.7	.8	11,140
Moisture and ash free . . .	-	45.6	54.4	-	.9	12,340

Additional strippable reserves may be proven south and west of the presently delimited reserve. Data indicating the depth of cover are not presently available; therefore, estimates of stripping limits cannot be determined.

The Pust bed dips about 20 to 30 feet per mile; dip is eastward in the western part of the deposit and northward in the eastern part. The coal lies on soft gray clay, and the overburden is predominantly massive, friable, fine- to medium-grained sandstone interbedded with poorly indurated shale.

Location 30: North Fork Thirteen Mile Creek Deposit

The North Fork Thirteen Mile Creek deposit (fig. 26) is roughly horseshoe-shaped. It lies in Tps 20 and 21 N, R 53 E, and T 20 N, R 54 E. At this location the Pust coalbed ranges in thickness from 10 to 43 feet and averages about 25 feet. It is generally free from partings. The estimated reserve is 225.1 million tons under less than 120 feet of overburden. Estimated stripping ratio overall is 3 cubic yards of overburden per ton of coal. Analyses (9) from nearby mines indicate that the composition of the coal in this reserve is within the high-low range shown on table 6.

Further exploration to the south should prove additional strippable reserves totaling 100 to 150 million tons.

The Pust coalbed lies on gray clay. Overburden consists predominantly of friable, fine- to medium-grained sandstone interbedded with soft, gray shales and one or two thin lenticular beds of lignite. A deposit of terrace gravel, 5 to 15 feet thick, underlies the surface in a half-mile-wide strip along the west bank of the North Fork Thirteen Mile Creek in the southern half of the deposit.

Southern McCone County Area (7)

Location and Geographic Features

Southern McCone County, Mont., an area of about 1,500 square miles along the Missouri-Yellowstone River divide, is extensively underlain by coal. The southeastern half of the county in particular is favorably endowed with thick coalbeds lying within strippable depths. The county is bordered on the north by the Missouri River, but lies essentially within the drainage of Redwater Creek and the westward flowing tributaries of Big Dry Creek. Drainage of the southeastern edge of the county is to the Yellowstone River to the south.

Altitudes in McCone County range from 1,960 to 3,300 feet, a total relief of 1,340 feet. Limited areas, particularly near the Missouri River flood plain, are characterized by bare steep slopes forming a "badland" topography. By far the greater part of McCone County consists of long, gentle slopes, only moderately incised, that provide much rolling grassland.

Circle, the largest town (1960 pop. 1,117) and county seat, is in the southeastern part of the county near the center of the potentially strippable coal reserve. Brockway (1960 pop. 185) is the second largest. The economy of the entire region is based on farming. Principal crops are wheat, flax, and hay; secondary crops are corn, oats, barley, and garden produce. Many cattle and some sheep and hogs are raised.

The main line of the Great Northern Railway parallels the north side of the Missouri River, just north of McCone County. Main lines of the Northern Pacific Railway and the Milwaukee Road parallel the Yellowstone River about 30 miles south of McCone County. The Redwater branch of the Northern Pacific, the only railroad in the county, extends from Glendive through Circle to its terminus at Brockway. This branch line crosses part of the coalfield and would serve as the nearest rail outlet for production.

State Highways 13, 20, and 20S and several county roads cross the coal-bearing area and could provide needed basic access routes to potential strip mines.

Coalfield Geology

The Fort Union Formation is about 1,100 feet thick in McCone County. In this portion of Montana it is composed of a lower part, the Lebo Member, and an upper part, the Tongue River Member. The Lebo Member, some 400 feet thick, consists of beds of white sandy clay and brownish sandstone, cross-bedded in places, alternating with nearly black argillaceous shale. Except for the U (Big Dirty) bed at its base, the Lebo Member contains only a few lenses of coal, all of which are in the basal 100 feet.

The Tongue River Member, overlying the Lebo Member, is composed of about 700 feet of predominantly yellowish or light-colored sandstones and sandy shales. Lettering from the top down, the bottom 400 feet of the Tongue River member contains four potentially important coalbeds, the P, Q, R, and S. These four beds are quite extensive; other beds in this sequence, and in the top 300 feet, are relatively local and unimportant.

The axis of a syncline more or less follows the trend of Redwater Creek across the southeastern part of McCone County. Along the axis of the syncline, the beds lie essentially flat. Dip into the syncline from both the north and south sides is not over 50 feet per mile and in much of the area is 20 feet per mile or less.

Mining Considerations

Sandstones and shales of the Tongue River Member are poorly cemented and could be moved by stripping equipment without prior blasting. It is possible that minor blasting of clinker may be required where high coal seams have burned, fusing the overlying sediments.

The essentially flat-lying beds permit easy stripping operations. It is likely that provisions for drainage will be necessary.

Coalbeds

Of the 11 named and several unnamed coalbeds in McCone County, only five are thick enough and of great enough horizontal extent to be of interest. Four of these, the P, Q, R, and S, are found in the lower half of the Tongue River Member, and one, the U, is the basal unit of the Lebo Shale Member of the Fort Union Formation.

Bed P, the highest in the stratigraphic section, ranges in thickness from 2 to 9 feet. Average thickness is 5 feet. From the 74 available measured sections, it is apparent that this bed, although extensive, is quite variable in thickness.

The stratigraphic interval between beds P and Q ranges from 55 to 100 feet. The range in thickness of the Q bed, based on 101 measured sections, is 2.1 to 8 feet, average thickness being 3.6 feet. Because the thicker measured sections are erratically spaced, and because the bed as a whole is quite thin, the Q bed will not be considered as a source of strip mine coal for many years.

Bed U, also known as the Big Dirty, is the basal unit of the Lebo Shale. Thus, this bed is also the basal unit of the Fort Union Formation. In various parts of the McCone County area, the stratigraphic interval between the Q and U beds ranges between 550 and 875 feet. As the name "Big Dirty" implies, the coalbed characteristically contains many impurities and is extremely variable in quality, although in some places good coal is present. The maximum reported bed thickness is 20 feet in sec 3, T 20 N, R 44 E, where the coal is quite impure. Because of its impurities, the bed would seem to have little economic potential even though it is present beneath an extensive area.

Strippable Deposits

Location 31: R Deposit

Bed R is stratigraphically 60 to 145 feet below bed Q. The 50 available measured sections indicate a range in thickness from 1.7 to 7 feet. Average thickness is 4 feet. The thicker part of the bed is in T 17 and 18 N, R 44 E, where 9 measured sections indicate a thickness range from 4 to 7 feet and average thickness of 5.75 feet (fig. 27).

By using the outcrop trace of bed Q as a stripping limit, bed R is estimated to be within 60 to 145 feet of the surface under 29.6 square miles. The total reserve in bed R under this area should be 196.1 million tons. The nearest place to the deposit for which an analysis of the R coal has been published (7) is the Aus mine in sec 32, T 19 N, R 48 E. The proximate analysis by the Bureau of Mines follows:

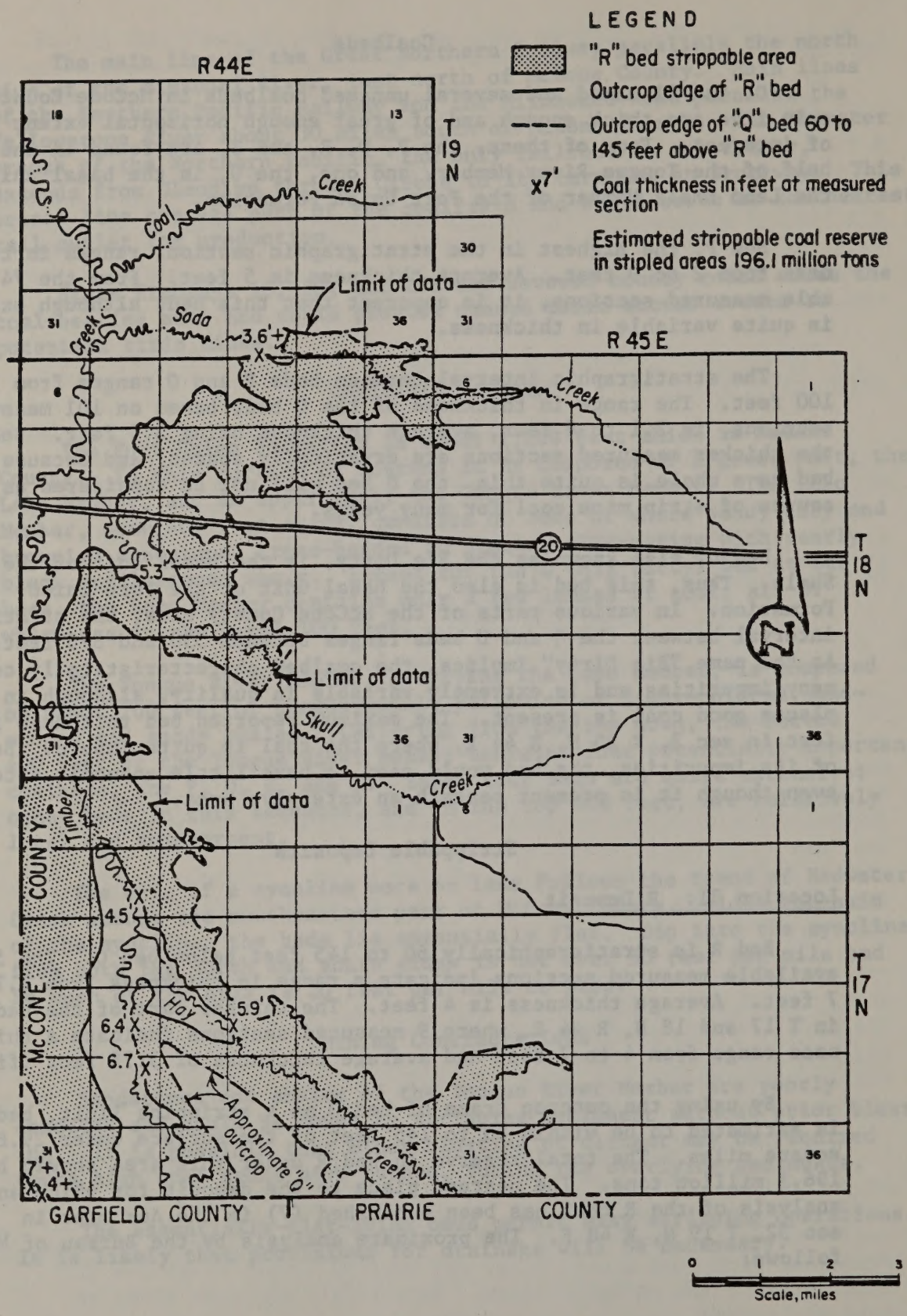

FIGURE 27. – R Deposit, Southern McCone County Area.
(Based on plate 1, U.S. Geol. Survey Bull. 905)

Form of analysis	Composition, percent[1/]					Heating value, Btu per lb
	Moisture	Volatile matter	Fixed carbon	Ash	Sulfur	
As received . . .	25.8	31.2	37.1	5.9	0.3	8,160
Moisture free . .	-	42.1	50.0	7.9	.4	11,000
Moisture and ash free . . .	-	45.7	54.3	-	.4	11,940

1/ U.S. Bureau of Mines data.

It is suggested that bed R should be within strippable depth and of comparable thickness under adjacent parts of T 16 to 18 N, R 43 E, and T 16 N, R 44 E.

Location 32: S Deposits

Bed S is 50 to 140 feet below bed R. This interval, combined with the persistence of both beds, permitted using the outcrop trace of the beds as a basis for delimiting the strippable portion of bed S under less than 140 feet of cover (fig. 28). It is recognized that parts of the reserve that underlie Circle, Brockway, the highway, and the railroad, probably will not be recovered. It is possible, however, that compensating new areas can be added as more complete data are obtained.

The S bed ranges in thickness from 3 to 15 feet. It is probable that the 3-foot measurements within the outlined area are incomplete sections. Average thickness is estimated to be 6.75 feet. Indicated total reserve is 1,165 million tons under the estimated strippable area of 149.84 square miles. No analyses for the S bed have been published.

Missouri River North Area (3, 8)

Location and Geographic Features

The Missouri River North area is bounded on the south by the Missouri River and on the north by the Canadian border. Its eastern boundary is the Montana State line, and the west side of R 53 E is the western limit.

Big Muddy Creek is the principal drainage within the area. This stream, flowing easterly in the northwestern part of the area, turns southward through the central part of the area and empties into the Missouri River. Montana State Highways 16 and 5 are the principal automotive access routes to the area. The Great Northern Railway serves the area by means of a branch line in the northern and central regions and the main line along the southern boundary.

The area, a part of the Great Plains, is a rolling prairie. The maximum relief is about 750 feet, and local differences in altitude usually are limited to about 150 feet. Much of the area is agricultural land and the principal crop is wheat; cattle raising is also an important industry.

Coalfield Geology

Surficial deposits include till, outwash deposits, pond deposits, gravels, alluvium, and dune sand. Oldest of the surficial deposits is the Flaxville Formation, which is composed of sand, clay, and gravel.

The Fort Union Formation, containing the lignite deposits, underlies the Flaxville Formation. The Fort Union varies considerably in thickness but has a maximum exposed thickness of about 600 feet. It consists of a thick yellowish-brown sequence of interbedded sand, sandstone, siltstone, clay, argillaceous shales, and lignite.

Coalbeds

Coalbeds in the area have been mapped by the U.S. Geological Survey. Beekly (3), in discussing the lignite resource, reports that of 15 lignite beds in the area the Culbertson field east of Big Muddy Creek and the Fort Peck field west of Big Muddy Creek--"six have thicknesses of 3 feet or more at all points along their outcrops accessible for measurement. The outcrops of these beds are continuous for distances of from 5 to 30 or 40 miles. Three of the nine remaining beds are more than 3 feet thick at a number of localities on the outcrop of each bed, though exposures are not sufficiently extensive to give assurance of their persistency throughout a large area. The remaining six beds are lenticular in character and, though in most places they contain less than 3 feet of lignite, their thicknesses are known to range from a few inches to 4 or 5 feet."

Strippable Deposits

Some of the strippable lignite deposits in the area are the Fort Kipp, Reserve, Coalridge, and Lanark deposits.

Location 33: Fort Kipp Deposit (11, 12)

The Fort Kipp deposit (fig. 29), in Tps 28-29 N, Rs 53, 54, and 55 E, is in Roosevelt County, Mont. At its furthermost point it is only 8 miles from the Missouri River and at its closest is adjacent to the river valley. The main line of the Great Northern Railway is immediately adjacent to the southern edge of the deposit. Moreover, U.S. Highway 2 crosses the southeast portion.

Sedimentary rocks of Tertiary and Quarternary age are exposed in the area, principally along the walls of the stream valleys. Most of

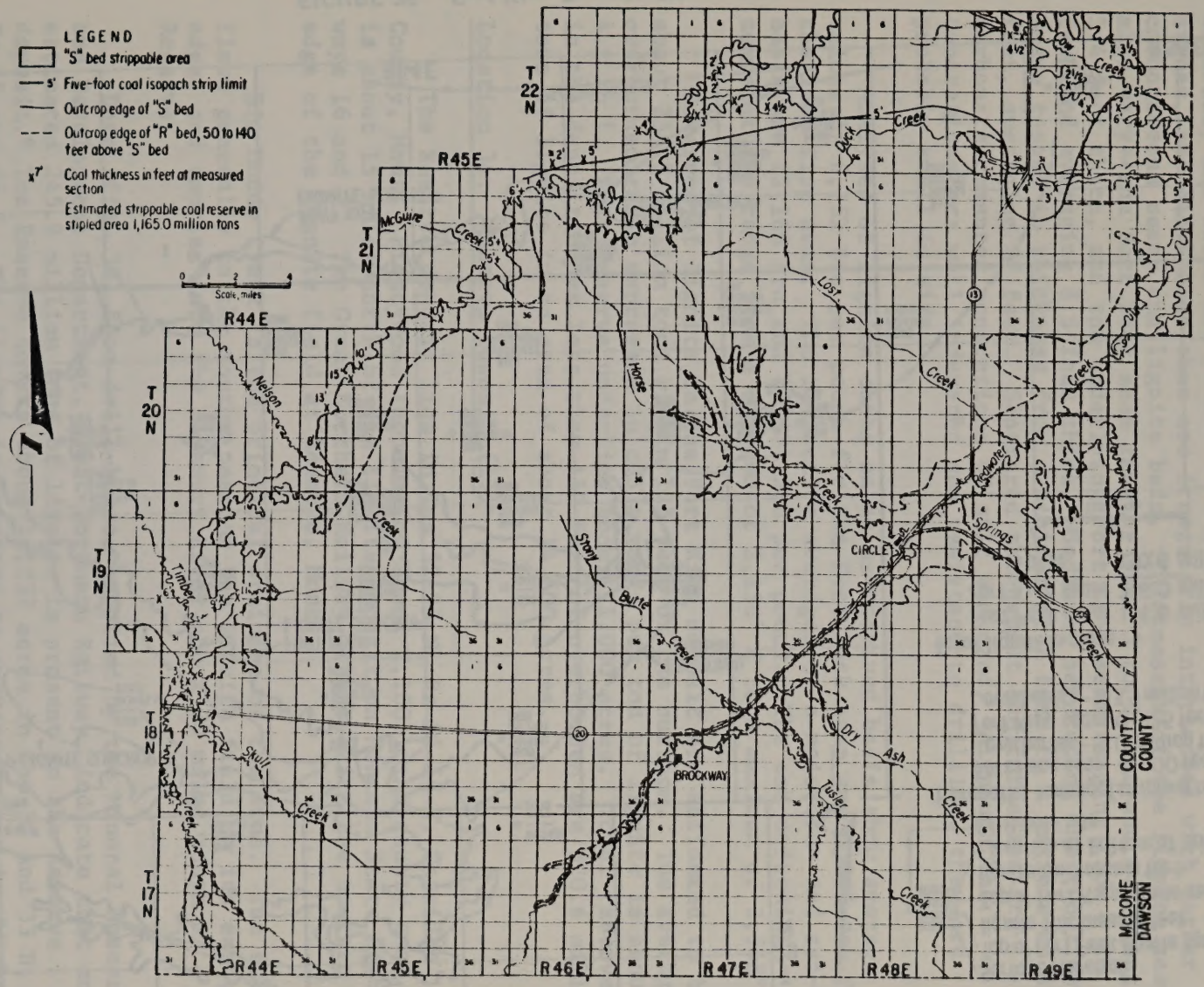

FIGURE 28. – S Deposits, Southern McCone County Area.
(Based on plate 1, U.S. Geol. Survey Bull. 905)

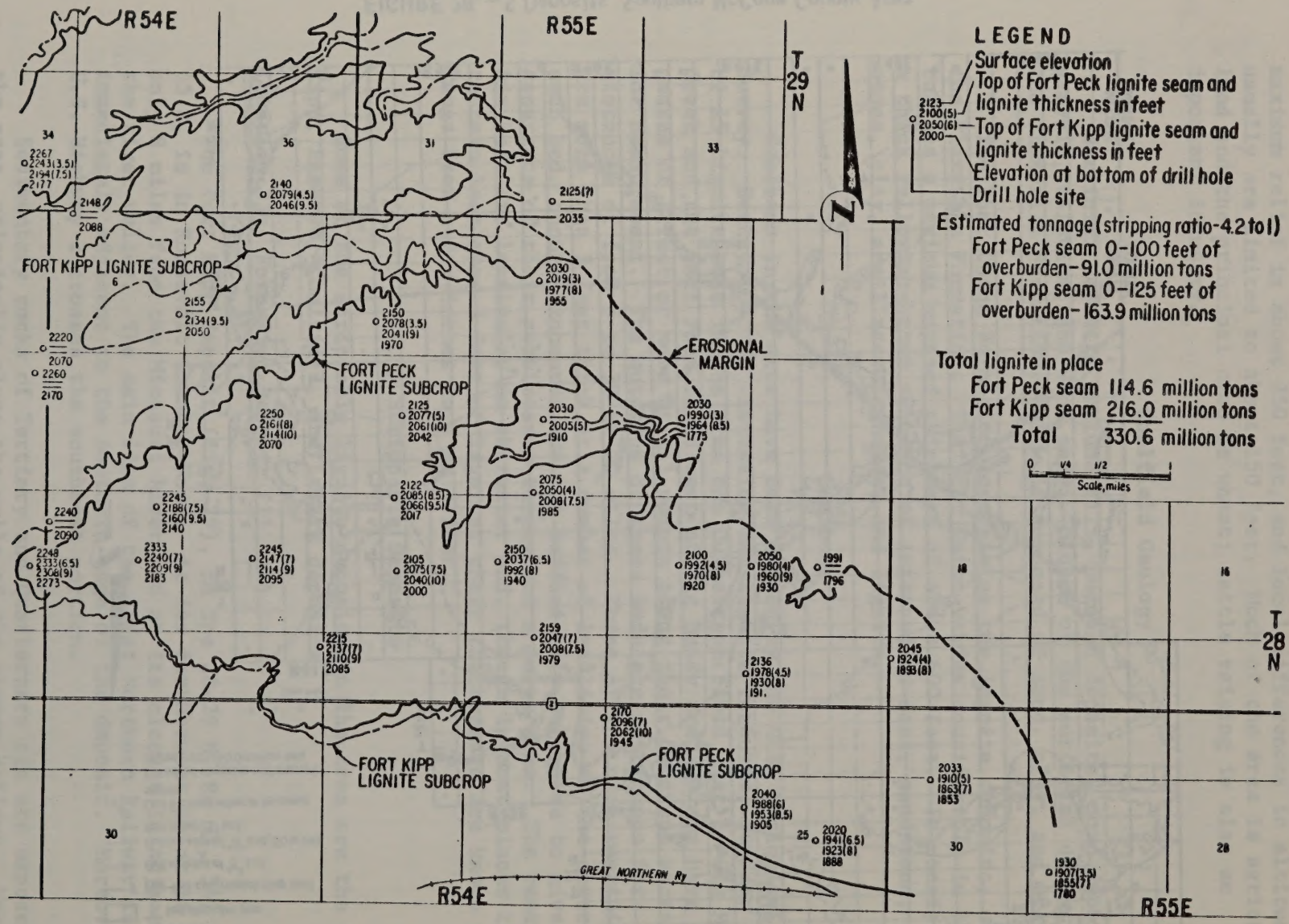

FIGURE 29. – Fort Kipp Deposit, Missouri River North Area.
(Data from Great Northern Railway Co.)

the Tertiary rocks are covered by a layer of glacial materials that varies greatly in thickness.

The Fort Union Formation varies widely in color and composition. Generally the rocks are yellow to light-buff colored sandstones, siltstones, and claystones that are irregularly interbedded with darker carbonaceous seams and lignite beds. Thicknesses of the lignite seams also vary--the Fort Peck seam ranging from 3 to 9 feet and averaging 5.4 feet thick, and the underlying Fort Kipp seam ranging from 7 to 10 feet and averaging 8.5 feet thick. Sediment separating the two lignite seams ranges in thickness from a minimum of 7 feet to a maximum of 49 feet, averaging 27 feet. Scattered throughout the formation are carbonate-cemented concretions of silt and sand. Although the concretions are well indurated and resistant to drilling, they are probably small in size.

Analyses of lignite cores on an as-received basis show average heat values of 6,751 Btu per pound for the Fort Peck seam and 6,805 Btu for the Fort Kipp seam. The respective averages on a moisture- and ash-free basis are 12,168 Btu and 12,071 Btu per pound. The ash softening temperatures range from a minimum of 2,130° F to a maximum of 2,548° F.

Reserves of lignite in the Fort Kipp deposit are estimated to be about 254.9 million tons within 125 feet of the surface. The average overburden ratio expressed in cubic yards per ton of lignite is about 4.2 to 1. This reserve underlies about 11,000 acres. Total reserves in the deposit under less than 150 feet of overburden are 330.6 million tons of lignite in an area of about 14,500 acres.

Location 34: Reserve Deposit (13)

The Reserve deposit lies in Tps 32-33 N, Rs 54-55 E, Sheridan County, Mont. Plentywood (population about 2,100), the county seat, is about 15 miles north of the lignite deposit on Montana State Highways 16 and 5. The Great Northern Railway tracks skirt the eastern edge of the lignite field at Reserve, Mont.

Big Muddy Creek is the principal drainage of the area. The stream flows generally to the south, passing the lignite field on its eastern edge, and empties into the Missouri River about 30 miles south of Reserve.

Data (fig. 30) from drill holes, supplied by the Mineral Research and Development Department, Great Northern Railway, indicate that an estimated 245.9 million tons of lignite is present in the Reserve deposit. The Reserve covers about 18,237 acres in Tps 32 and 33 N, Rs 54 and 55 E. The lignite is reported to average 8 feet in thickness in T 33 N, Rs 54 and 55 E, and to be covered by 1,038 million cubic yards of overburden to give an overburden-to-coal ratio of 5.8 to 1. The lignite reportedly averages 7 feet in thickness in T 32 N, Rs 54

and 55 E, and the overburden-to-coal ratio is 6.5 to 1. Analyses on an as-received basis for two core samples from the deposit follow (13):

Location	Composition, percent					Heating value, Btu per lb
	Moisture	Volatile matter	Fixed carbon	Ash	Sulfur	
Sec 14, T 33 N, R 54 E	34.5	26.5	25.0	14.0	2.3	6,343
Sec 19, T 33 N, R 55 E	38.5	24.8	29.0	7.6	.4	6,599

Drill logs suggest that other lignite seams are present that might well be recovered if this deposit were mined.

Location 35: Medicine Lake Deposit (13)

The Medicine Lake deposit (fig. 30), several miles west and south of the Reserve deposit, could be an extension of the Reserve field. Geologists of the Great Northern Railway Co. estimate that the Medicine Lake deposit contains 58 million tons of lignite in a bed having an average thickness of about 9 feet. The deposit is within an area of about 3,740 acres and under less than 110 feet of overburden. Analyses on an as-received basis for two core samples from the deposit follow (13):

Location	Composition, percent					Heating value, Btu per lb
	Moisture	Volatile matter	Fixed carbon	Ash	Sulfur	
Sec 9, T 32 N, R 54 E	37.0	26.3	29.5	7.2	1.0	6,870
Sec 23, T 32 N, R 54 E	37.4	26.3	28.5	7.7	.7	6,692

Location 36: Coalridge Deposit (13)

The Coalridge deposit is about 18 miles northeast from the Reserve deposit. Thirty-three drill logs (table 7) supplied by the Great Northern Railway Co. indicate a strippable reserve of approximately 600 million tons in an area of about 30 square miles. The drill hole sites are shown on figure 31. Overburden is clay, shale, and glacial debris. No analyses are available but composition of the coal would be similar to the analyses given for the Reserve and Medicine Lake deposits.

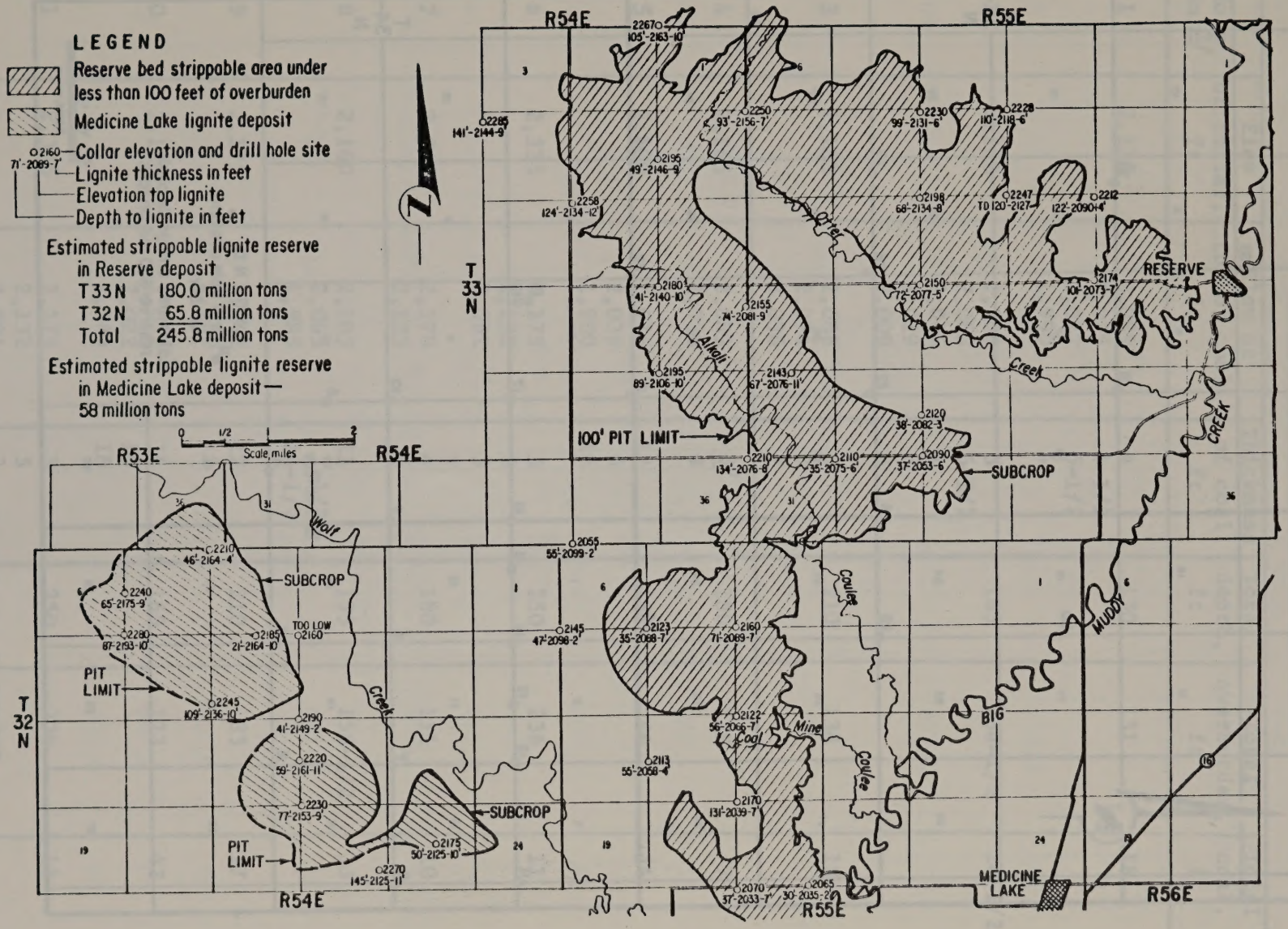

FIGURE 30. – Reserve and Medicine Lake Deposits, Missouri River North Area.
(Data from Great Northern Railway Co.)

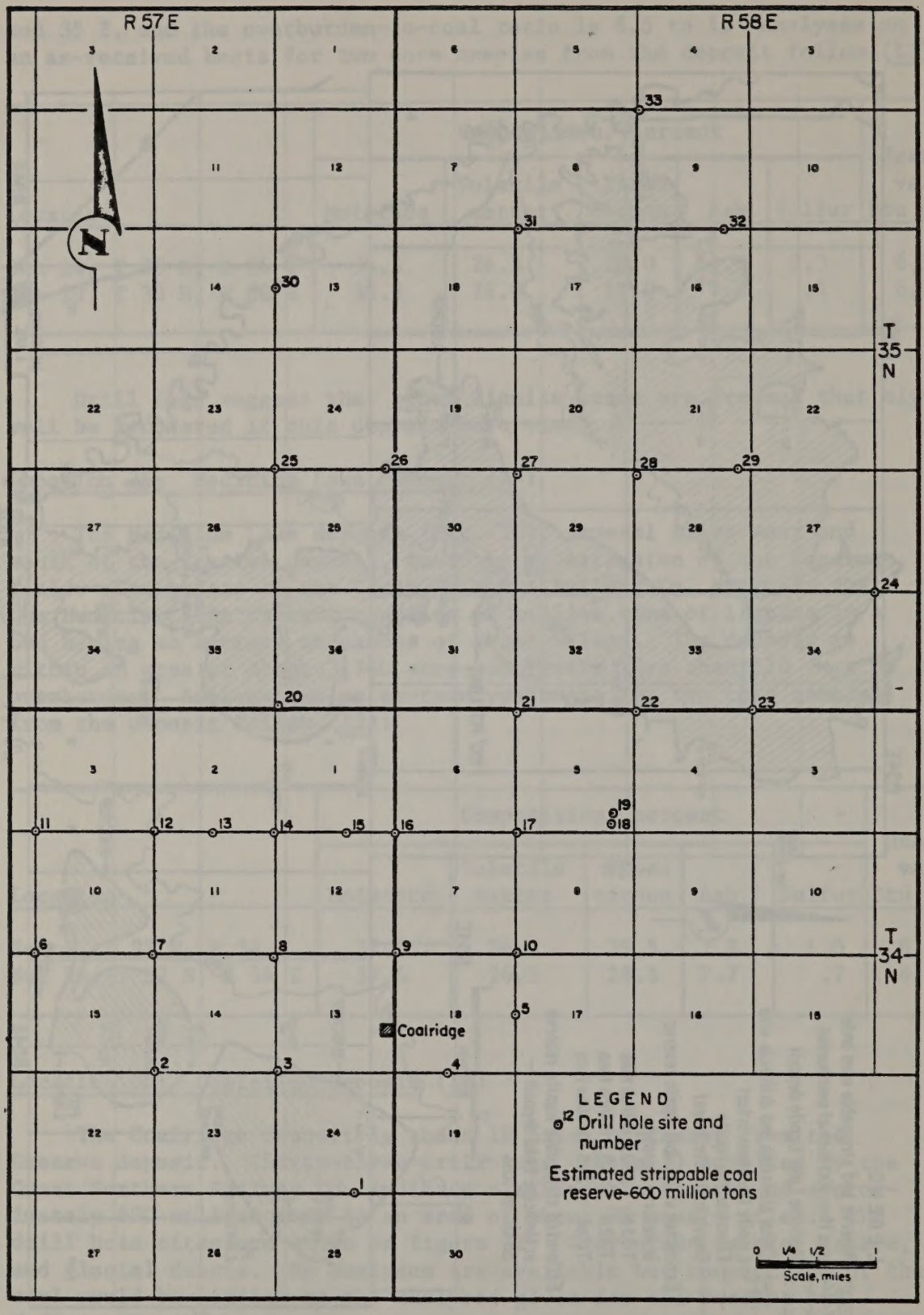

FIGURE 31. – Coalridge Deposit, Missouri River North Area.
(Data from Great Northern Railway Co.)

TABLE 7. - Drill hole data, Coalridge deposit[1/]

Hole No.[2/]	Elev of collar, ft	Elev at top of coal, ft	Thickness of coal, ft	Total depth, ft	Total overburden, ft	Total coal, ft
1	2,135	2,089	4	150	131	18
		2,075	4-1/2			
		2,022	5-1/2			
		1,990	4			
2	2,160	2,106	3	165	134-1/2	24-1/2
		2,063	6-1/2			
		2,046	4			
		2,019	3			
		2,009	8			
3	2,185	2,088	8	210	138	18
		2,074	3			
		2,036	7			
4	2,165	2,083	[3/]	180	129	7
		2,036	7			
5	2,100	2,076	12	150	86	34
		2,036	6			
		1,980	16			
6	2,335	2,175	3	250	236	11
		2,132	5			
		2,091	3			
7	2,240	2,170	4	180	111	10
		2,125	6			
8	2,160	2,105	11	195	156-1/2	33
		2,065	7-1/2			
		1,985	14-1/2			
9	2,175	2,042	12	210	83	17
		1,980	5			
10	2,120	2,072	14	165	123	42
		2,022	10			
		1,983	18			
11	2,335	2,175	3	250	236	11
		2,132	5			
		2,091	3			

TABLE 7. - Drill hole data, Coalridge deposit[1]--Continued

Hole No.[2]	Elev of collar, ft	Elev at top of coal, ft	Thickness of coal, ft	Total depth, ft	Total overburden, ft	Total coal, ft
12	2,195	2,142	10	195	147	35-1/2
		2,100	2			
		2,097	6			
		2,032	19-1/2			
13	2,170	2,137	8	60	33	8
14	2,120	-	-	165	-	-
15	2,195	2,091	10	225	169-1/2	40-1/2
		2,059	10-1/2			
		2,005	20			
16	2,180	2,103	11	180	135	30
		2,063	6			
		2,058	2			
		2,028	13			
17	2,120	2,076	12	150	100	34
		2,027	6			
		2,002	16			
18	2,100	2,081	6	130	117	13+
		2,049	4			
		1,973	3+			
19	2,135	2,099	[3]	45	-	-
20	2,170	2,102	11	210	159	43
		2,068	9			
		1,991	23			
21	2,142	2,107	10	146	117	24
		2,050	4			
		2,011	10			
22	2,115	1,979	6	144	136	6
23	2,090	1,977	15	165	113	15
24	2,105	-	-	150	-	-

TABLE 7. - Drill hole data, Coalridge deposit[1/]--Continued

Hole No.[2/]	Elev of collar, ft	Elev at top of coal, ft	Thickness of coal, ft	Total depth, ft	Total overburden, ft	Total coal, ft
25	2,250	2,095 2,056 2,004	10 8 20+	266	128	38+
26	2,170	2,113 2,066 2,023	10 9 18	180	128	27
27	2,185	2,130 2,107	7 7	135	71	14
28	2,090	1,991	15	120	99	15
29	2,070	-	-	120	-	-
30	2,210	2,140 2,091 2,014	11 9 22	238	70	11
31	2,165	2,036	10	225	129	10
32	2,125	2,042 1,996	5 21	165	124	26
33	2,110	2,016 2,001	11 6	135	98	17

1/ Mineral Research and Development Department, Great Northern Railway Co.
2/ Refers to drill hole numbers on figure 31.
3/ Unknown

In a block of about 10 square miles just northeast of Coalridge the logs of drill hole Nos. 5, 9, 10, 17, 18, 21, and 23 define 250 million tons of strippable coal in one to three beds and under less than 125 feet of overburden.

The coalbeds range from 4 to 18 feet in thickness and the average total coal thickness is 25-1/2 feet. Average thickness of the overburden, including intraburden, is 106 feet.

Another block of about 10 square miles in T 35 N, R 58 E, contains 200 million tons of strippable coal in one to three coalbeds under less than 130 feet of overburden. As shown by the logs of drill hole Nos. 26, 27, 28, 31, 32, and 33 the coalbeds range in thickness from 5 to 21 feet and the average total coal thickness is almost 20 feet. Average thickness of the overburden, including intraburden, is 105 feet.

Along the east side of Tps 34 and 35 N, R 57 E a block of about 13 square miles contains strippable coal in one and two coalbeds that range in thickness from 8 to 20-1/2 feet. The logs for drill hole Nos. 1, 2, 3, 8, 12, 13, 15, 16, 20, 25, and 30 show a maximum overburden of 126 feet and an average overburden of 85 feet. Average total coal thickness is 14 feet. The Coalridge channel, (22) carved by glacial melt water, crosses the deposit from northeast to southwest and has eroded most of the near surface coal from about 3 square miles. Hole No. 14, drilled near the center of the channel, penetrated only glacial till. The strippable reserve in the remaining 10 square miles is approximately 150 million tons.

Location 37: Lanark Deposit

The Lanark deposit is just north of the Missouri River and includes all or parts of Tps 26-28 N, Rs 55-59 E, in Roosevelt County, Mont. Of several lignite beds in the area, two beds attain thicknesses of 7 feet or more and, from the data available, seem to be reasonably consistent in outcrop thicknesses of 5 feet or more. These beds are designated as the E or Lanark and F or Archer.

The lignite beds are in the Fort Union Formation and have a general dip to the southeast of about 15 feet per mile. Overburden, according to drill hole data, consists of glacial till, siltstone, claystone, and some hard limestone concretions. Average analyses on an as-received basis of the Archer and Lanark seams in the Lanark deposit, as reported by the Great Northern Railway, are as follows (11):

Bed	Composition, percent					Heating value, Btu per lb
	Moisture	Volatile matter	Fixed carbon	Ash	Sulfur	
Archer	38.1	25.5	32.3	4.1	1.2	6,724
Lanark	38.3	25.4	30.0	6.3	.4	6,853

The Lanark deposit, about 7 miles north of the present channel of the Missouri River, is bordered by the Great Northern Railway on the southern edge of the field. Access to the field is by way of U.S. Highway 2, about midway between Culbertson (population 919) and Bainville (population about 300).

The Archer and Lanark beds were explored by drilling, and results were supplied by the Great Northern Railway. The drill hole sites are shown on figure 32 and the logs are listed in table 8.

A reserve of about 100 million tons of lignite is indicated in the Archer and Lanark beds under less than 120 feet of overburden. It is estimated that the Archer seam is about 8 feet thick and that the average overburden thickness is about 63 feet. The Lanark bed is about 7 feet in thickness, and the intraburden averages about 53 feet in thickness.

TABLE 8. - Drill hole data, Lanark deposit[1/]

Hole No.[2/]	Elev of collar, ft	Elev at top of Archer bed, ft	Coal thickness, Archer bed, ft	Elev at top of Lanark bed, ft	Coal thickness Lanark bed, ft	Total depth, ft
1	2,100	2,047	8	1,995	7	195
2	2,135	2,055	8	1,994	9	165
3	2,082	2,036	8	1,979	7	135
4	2,108	2,035	9	1,974	8	150
5	2,083	2,040	7	1,976	8.5	135
6	2,120	2,094	6	2,043	8	105
7	2,195	2,094	7	2,037	8	195
8	2,067	-	-	1,992	8	165
9	2,135	2,040	7	-	-	105
10	2,135	2,095	7	2,024	7	135
11	2,190	2,081	8	2,012	8	195
12	2,155	2,092	9	-	-	90
13	2,150	2,083	9	2,022.5	7.5	210
14	2,115	2,081.5	6	-	-	165
15	2,000	-	-	-	-	60
16	2,080	2,054	7	-	-	120
17	2,025	-	-	-	-	105
18	2,080	1,984	7	-	-	135
19	2,030	1,954	7	-	-	105
20	2,100	2,086	9	-	-	210
21	2,300	2,164	8	2,100	7	225
22	2,140	-	-	2,056	7.5	165
23	2,195	2,098	8	2,030	8	210
24	2,245	2,062	6	-	-	210
31	2,145	2,094	7.5	-	-	110
32	-	-	8	-	-	115

1/ Mineral Research and Development Department, Great Northern Railway Co.
2/ Refers to drill hole numbers on figure 32.

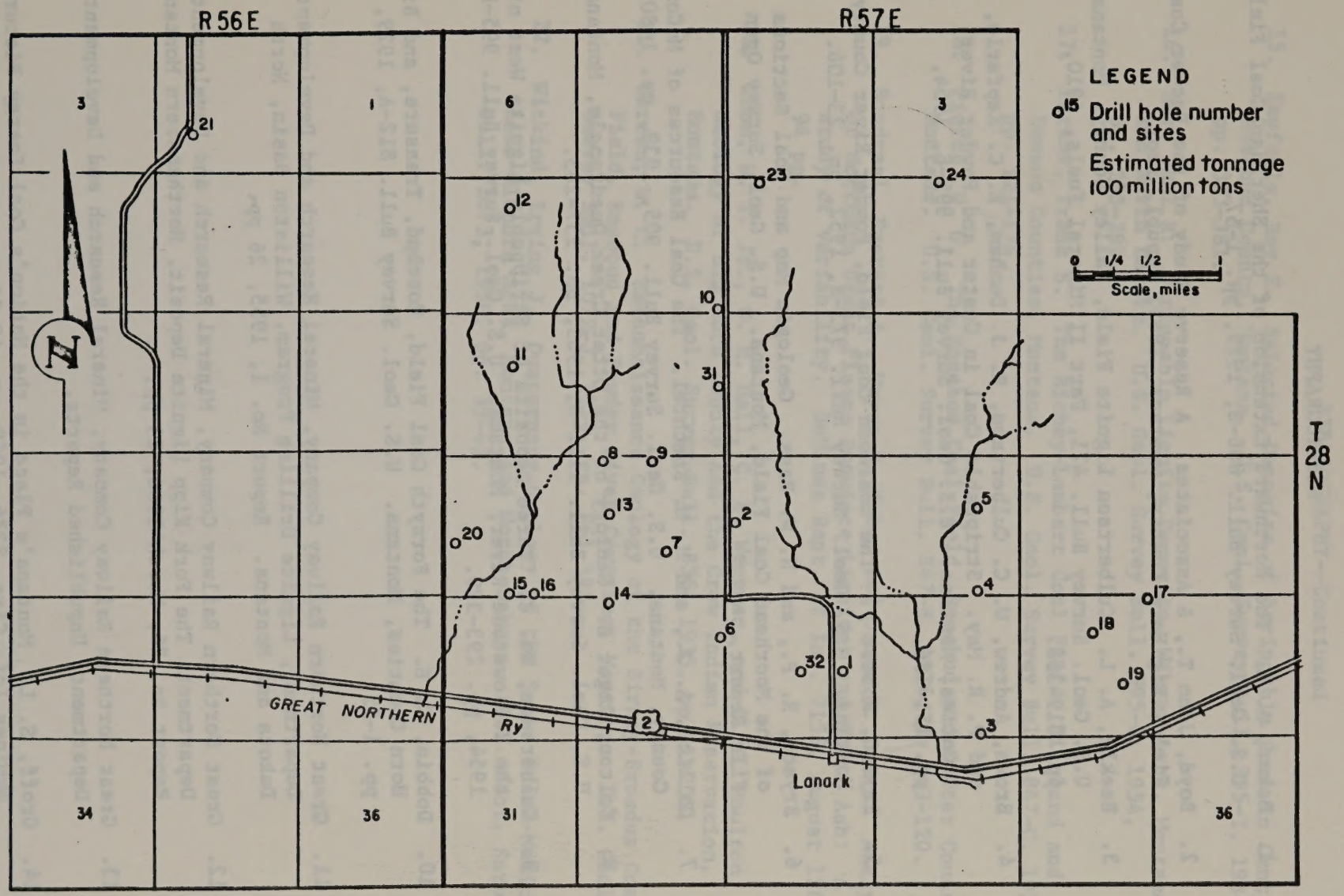

FIGURE 32. – Lanark Deposit, Missouri River North Area.
(Data from Great Northern Railway Co.)

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